COSEWIC
Assessment and Status Report

on the

Black Ash
Fraxinus nigra

in Canada

THREATENED
2018

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Black Ash

Scientific name
Fraxinus nigra

Status
Threatened

Reason for designation
Approximately 51% of the global range of this tree is found in Canada. Subpopulations in the central part of the distribution have been devastated by Emerald Ash Borer, an invasive beetle. This invasive species was first detected in Canada (Windsor, Ontario) in 2002 and has since expanded its range as far west as Winnipeg, Manitoba, and east to Bedford, Nova Scotia. Although, it has caused a modest overall decline in known numbers of ash in New Brunswick, Quebec, Ontario, and Manitoba to date, projections indicate that mortality rates will be greater than 90%, and ~73% of the Canadian population is likely to be affected within one generation (60 years) under current climate conditions. Emerald Ash Borer bio-controls have been initiated in parts of southern Ontario and Quebec, but their effectiveness is uncertain. Consequently, Emerald Ash Borer is expected to expand farther into this species' habitat with climate change.

Occurrence
Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Status history
Designated Threatened in November 2018.

COSEWIC
Executive Summary

Black Ash
Fraxinus nigra

Wildlife Species Description and Significance

Black Ash is a broad-leaved hardwood tree in the Olive family, growing to 15-20 m in height and 30-50 cm in diameter. The opposite, pinnately-compound leaves are 15-30 cm, with seven to 11 leaflets. The small flowers lack petals and sepals and appear in crowded clusters prior to leaf out. Fruit are elongated, winged samaras. Stalkless leaflets, samaras winged to the base, and a gap between the terminal and nearest lateral buds distinguish Black Ash from other ash species.

Black Ash wood is highly flexible and readily separates into thin strips, making it useful in applications requiring bending. It has been important for barrel hoops, chair seats, snowshoe frames and canoe ribs, and remains significant for use in First Nations basketry. The durable wood is valued commercially for tool handles, furniture, interior finishing and flooring. Numerous First Nations medicinal uses are reported, and it is commercially available in horticulture. Black Ash is a dominant species in many swamp forest and riparian ecosystems, in which it provides food and shelter for many species, including at least ten Canadian ash-specialist arthropods.

Distribution

Black Ash occurs from western Newfoundland to southeastern Manitoba and North Dakota, ranging southward to Iowa, Illinois, Virginia and Delaware. Black Ash range extends farther north than any other ash and approximately 51% of the species' global range is within Canada.

Habitat

Black Ash is predominantly a wetland species of swamps, floodplains and fens. It has an intermediate light requirement and a tendency toward greater abundance in more alkaline sites. Most sites in which it is dominant are flood prone, where its high tolerance of seasonal flooding appears to offer a competitive advantage. Black Ash also occurs widely in moist upland forests, but generally at lower densities than in wet areas.

Biology

Black Ash flowers in mid- to late spring and is wind-pollinated. Individuals are generally polygamous (unisexual and bisexual flowers borne on the same tree), but occasionally unisexual. Seeds ripen from late August to September and are dispersed by wind and water from October to the following spring. Good seed crops are produced irregularly at one to eight year intervals. Seeds exhibit deep physiological dormancy and germination requires exposure to moisture and both high and low temperatures. This may be significant in determining northern and southern range limits. Black Ash seeds retain viability in the soil from three to eight years. Black Ash can reproduce by seed at about 30 years old and can live up to 200-300 years. Vegetative reproduction is not known to occur, but extensive sprouting can occur from root crowns or cut stumps. Generation time for this report is estimated at 60 years, which may be an underestimate for this relatively long-lived, slow growing species.

Population Sizes and Trends

The Canadian population is incompletely understood, but estimates based on forestry data suggest it is in the range of 162 million mature trees. Emerald Ash Borer (EAB) is causing substantial ash mortality in parts of southern Ontario and Quebec. Mortality of ash species is little studied in Canada, but Black Ash is the most EAB-susceptible of all ashes in the northeast United States. EAB has not yet spread widely enough within Canada to have greatly reduced the Canadian Black Ash population, but rapid spread of EAB and extensive mortality of Black Ash are expected in less than one generation (60 years). Regional EAB-caused mortality of mature trees in the United States has reached 95-99% with similar rates in the longest affected parts of Canada. Several lines of evidence suggest, however, that effects may not reach that level throughout the Canadian range (see below).

Conversion of forest to other land uses since European settlement has produced significant declines in the Great Lakes Plains within the past three generations, but much of Black Ash's range lies north of heavily settled regions in areas where there is little evidence of substantial recent change. Declines linked to undetermined and potentially introduced disease have been suggested in Nova Scotia, Prince Edward Island and southeastern New Brunswick.

Threats and Limiting Factors

Black Ash is threatened by the introduced Emerald Ash Borer (EAB), an Asian wood-boring beetle that reached southwestern Ontario in 1992 and has since spread to Canadian sites up to 1,100 km northwest and 1,300 km northeast. EAB larvae feed on the inner bark and sapwood, eventually girdling and killing trees. Mortality of mature ash trees (all species) reached 99% within six years in parts of Michigan and Ohio, and Black Ash is the ash species most severely affected by EAB. Similar mortality of ash (all species) has been noted in the first and most heavily affected areas of southern Ontario. Based solely on observed rates of spread, all Canadian Black Ash could be affected within one generation

(60 years). Analysis suggests 27% of Black Ash in Canada could be protected from EAB under current climate because of cold minimum temperatures, though most or all of this protection could be lost within about one generation under predicted levels of climate warming. The establishment of introduced biological control agents, and the potential for post-EAB recovery (based on evidence from Red Ash) also suggest ultimate EAB-caused mortality in Canada may be less than 99%. Asian parasitoid wasps introduced for biological control are now well established in various parts of Black Ash's United States range, locally reducing EAB population growth by 50%, but their effects on ash survival are not yet clear. Introduction of biological control agents began in Ontario and Quebec in 2015.

Other potential range-wide threats of lesser immediacy or magnitude are: 1) unknown and potentially introduced pathogen(s) that appear to have caused major declines in Nova Scotia since 1958; 2) the Asian fungal disease, Chalara Dieback, which is causing extreme loss of the closely related European Ash in Europe, is virulent in Black Ash, but is not yet known in North America; and 3) Climate change, which is predicted to significantly reduce the region suitable for Black Ash within one to two generations.

Protection, Status and Ranks

Black Ash was listed under the *Nova Scotia Endangered Species Act* as Threatened in 2013, but it has no provincial or state level legal status in other jurisdictions. It receives some protection from provincial wetland and riparian policies through most of its Canadian range, and it is present in many protected areas. Black Ash currently has a global status rank of G5 (Secure). This rank and many other NatureServe state ranks pre-date the introduction of EAB and thus overestimate security of Black Ash. It is of conservation concern, independent of EAB, based on the following status ranks: SH (Historic) in the District of Columbia, S1S2 (Imperiled) in Nova Scotia, Delaware, North Dakota and Rhode Island, S2S3 (Imperiled to Vulnerable) in West Virginia and S3 (Vulnerable) in Manitoba, the Island of Newfoundland, Maryland and Virginia. Other Canadian provincial ranks, reviewed in 2016, are: S4 (Apparently Secure) in Ontario; S4S5 (Apparently Secure to Secure) in New Brunswick; and S5? (Questionably Secure) in Quebec.

TECHNICAL SUMMARY

Fraxinus nigra

Black Ash

Frêne noir

Range of occurrence in Canada (province/territory/ocean): Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador.

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines [2011] is being used)	60 years (estimated); reproduction from seed in the wild begins around age 30; vegetative reproduction, as defined by COSEWIC, is not known to occur; maximum age 200-300 years (see *Biology*)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, declines observed and projected because of Emerald Ash Borer.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown; potentially very significant from EAB within 2 generations
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	>6.4%, based on habitat loss over past three generations (see *Habitat Trends*); Observed declines from EAB are believed to represent only a small fraction of the Canadian population as of 2017
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	A greater than 50% reduction in the total number of mature individuals over the next 3 generations is projected because of the effects of Emerald Ash Borer.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	A greater than 50% reduction in the total number of mature individuals over the next 3 generations is suspected because of the effects of Emerald Ash Borer.
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No, decline not clearly reversible if EAB persists b. Yes, cause of decline understood c. No, decline not ceased
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	2,004,000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	Unknown, but likely on the scale of 500,000 km² (see *Extent of Occurrence and Area of Occupancy)*
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Unknown. Potentially 100s or 1000s assuming only 72.8% of Canadian population is currently climatically susceptible to EAB. Minimum two locations (affected by EAB, and not yet affected) if climate warming eliminates climatic protection from EAB. (see *Threats* and *Number of Locations*)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Some decline inferred and projected with loss of small, peripheral subpopulations in southwestern-most Ontario (see *Threats*)
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, inferred and projected declines with loss of small subpopulations, given 90%+ anticipated declines in regions affected by Emerald Ash Borer (see *Threats*)
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, inferred and projected declines with loss of small subpopulations, given 90%+ anticipated declines in regions affected by Emerald Ash Borer (see *Threats*)
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No. Number of locations is determined by threat of Emerald Ash Borer, or by other less significant threats.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Minor declines in area and quality of habitat, primarily around settled regions, with ongoing land conversion for development.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Many thousands of subpopulations in Canada. The subtotals for N Mature Individuals are based on provincial boundaries.	
Ontario	est. 82,809,273 (51.3%)
Quebec	est. 71,321,192 (43.1%)
New Brunswick	est. 8,300,000 (5.3%)
Manitoba, Nova Scotia, Prince Edward Island, Newfoundland (Island)	undetermined small subpopulations, collectively <1%
Total	Approximately 162 million (see *Abundance*)

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not assessed

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes. The calculated overall threat impact for the species across Canada is Medium.

Threats that scored "Negligible" in the Threats Calculator are not listed here, but are discussed under *Threats*.

i. Emerald Ash Borer (IUCN Threat 8.1 Invasive Non-native Species). Threat impact = Medium.
ii. Undetermined Disease or Insect Species in Atlantic Canada (IUCN Threat 8.4 Problematic Species/Diseases of Unknown Origin). Threat impact = Unknown.
iii. Logging and Wood Harvesting (IUCN Threat 5.3). Threat impact = Low

What additional limiting factors are relevant?

There is widespread, but poorly understood, observation of low vigour and high mortality of Black Ash in the northeast United States collectively called "ash dieback". Speculated causes relating to winter freeze-thaw and summer drought could be exacerbated by climate change. The same undetermined disease or insect affecting Black Ash in Atlantic Canada could also be a contributing factor. See *Limiting Factors*.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The species is still common in northern Minnesota, Vermont, New York, New Hampshire and Maine, but all adjacent United States subpopulations are or will likely be heavily affected by Emerald Ash Borer within one generation.

Is immigration known or possible?	Yes, immigration across the border in areas with healthy populations would presumably be regular (see *Dispersal and Migration* and *Rescue Effect*), but not a significant factor at a national scale. Immigration well into Canada from the U.S.A. is likely rare.
Would immigrants be adapted to survive in Canada?	Yes (in areas not yet affected by EAB). Conditions are similar on either side of the border.
Is there sufficient habitat for immigrants in Canada?	Yes. Habitat is not believed to be significantly limiting in most of range.
Are conditions deteriorating in Canada?[+]	Yes. Emerald Ash Borer is rapidly spreading and causing increasing mortality.
Are conditions for the source population deteriorating?[+]	Yes. Emerald Ash Borer is rapidly spreading and causing increasing mortality.
Is the Canadian population considered to be a sink?[+]	No. The Canadian population is neither dependent upon nor significantly affected by immigration.
Is rescue from outside populations likely?	No. Immigration will not significantly affect impacts from Emerald Ash Borer.

Data Sensitive Species

Is this a data sensitive species? It is considered data sensitive in Nova Scotia by Nova Scotia Department of Natural Resources.

Status History

COSEWIC: Designated Threatened in November 2018.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** Meets criteria for Endangered, A3ce+4ce, based on predicted areas of susceptibility, but designated Threatened, A3ce+4ce, due to factors including effectiveness of Emerald Ash Borer (EAB) bio-controls and EAB winter survivability, that may reduce mortality over the projected period.

Reasons for designation:
Approximately 51% of the global range of this tree is found in Canada. Subpopulations in the central part of the distribution have been devastated by Emerald Ash Borer, an invasive beetle. This invasive species was first detected in Canada (Windsor, Ontario) in 2002 and has since expanded its range as far west as Winnipeg, Manitoba, and east to Bedford, Nova Scotia. Although, it has caused a modest overall decline in known numbers of ash in New Brunswick, Quebec, Ontario, and Manitoba to date, projections indicate that mortality rates will be greater than 90%, and ~73% of the Canadian population is likely to be affected within one generation (60 years) under current climate conditions. Emerald Ash Borer bio-controls have been initiated in parts of southern Ontario and Quebec, but their effectiveness is uncertain. Consequently, Emerald Ash Borer is expected to expand farther into this species' habitat with climate change.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered, A3ce+4ce, as declines are projected to be over 50%. A reduction in the index of area of occupancy, due to EAB-caused mortality, will likely accompany the projected decline in the total number of mature individuals.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria. EOO is 2,000,000 km^2 and IAO is estimated to be 500,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. Total number of mature individuals is 162 million.
Criterion D (Very Small or Restricted Population): Although population is considered to have 2 locations, it is not a very small or restricted population and is not at risk of becoming critically endangered due to human activities or stochastic events in a very short period of time.
Criterion E (Quantitative Analysis): Not done.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2018)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Fraxinus nigra* Marshall

Original Description: Marshall, Arbust. Amer. 51. 1785

Synonyms (The Plant List 2017):

Fraxinus sambucifolia Lam.
Fraxinus americana L. var. *nigra* (Marshall) Weston
Fraxinus nigra L. var. *sambucifolia* (Lam.) Castig.
Calycomelia nigra (Marshall) Kostel.
Fraxinoides nigra (Marshall) Medik.
Leptalix nigra (Marshall) Raf.

English common name: Black Ash; occasionally also Basket Ash, Brown Ash, Swamp Ash, Hoop Ash, Water Ash, American Black Ash, Canadian Ash, Splinter Ash

French common name: Frêne noir; occasionally also Frêne gras

Aboriginal names:

wikp (Wolastoqiyik) (First Nations Forestry Program 2006),
wiskoq (Mi'kmaq) (First Nations Forestry Program 2006),
ehsa (Mohawk) (Willow 2011),
wiisagaak/ wiisagaatic (oog – plural; Ojibwe) (Densmore 1974; Meeker *et al*. 1993; Davidson-Hunt *et al*. 2005),
aagimaatig/ aagimaak/ aasaakamig/ aagamaatig (oog-plural; Ojibwe) (Densmore 1974; Meeker *et al*. 1993; Davidson-Hunt *et al*. 2005; Willow 2011)

Genus: *Fraxinus* L.

Family: Oleaceae (Olive Family)

Order: Lamiales (APG 2016)

Major Plant Group: Angiosperms – Eudicots (APG 2016)

No subspecific taxonomy is currently recognized for Black Ash. A treatment in which Manchurian Ash was considered a subspecies of Black Ash (as *Fraxinus nigra* ssp. *mandshurica*; Sun 1985) never gained acceptance (Gleason and Cronquist 1991; Farrar 1995; IPNI 2017; Brouillet *et al*. 2010+). Other subspecies and variety names under *Fraxinus nigra* are from very old sources in which Red Ash (*Fraxinus pennsylvanica*), White Ash (*Fraxinus americana*) and Carolina Ash (*Fraxinus caroliniana*) were all treated as subspecies or varieties of Black Ash (IPNI 2017).

Black Ash is not closely related to any other North American native ashes (Wallander 2008, 2013), and is placed in section *Fraxinus* with European Ash (*Fraxinus excelsior*) and Narrow-leaved Ash (*Fraxinus angustifolia*) of Europe and Manchurian Ash (*Fraxinus mandshurica*) of eastern Asia (Wallander 2013). All other native ashes in eastern Canada are classified in section *Melioides*, except for Blue Ash (*Fraxinus quadrangulata*), which is in section *Dipetalae* (Wallander 2013).

Morphological Description

Black Ash (Figures 1 and 2) is a broadleaved hardwood tree reaching a height of 15 m to 27 m (Grimm 1962; Farrar 1995; GoBotany 2017; maximum 37 m, from Clayton, Iowa - American Forests 2012). It typically does not exceed 50 cm in girth (Farrar 1995; maxima 97 cm and 148 cm from Ohio and Iowa [Pardo 1978; American Forests 2012]). The stout ascending branches form a narrow and open crown. Young trees above about 7 cm diameter develop bark with rounded, soft, corky ridges that are easily depressed or rubbed off. On older trees, the bark is grey with near-vertical, narrow, scaly strips (Harlow and Harrar 1979; Farrar 1995). Roots are shallow and wide-spreading (Harlow and Harrar 1979). Morphological features of leaves, buds, twigs and bark are well described in Farrar (1995) and many other sources.

The following characters collectively distinguish Black Ash from other Canadian ash species:

- generally 7-11 stalkless leaflets (vs. 5-9 stalked leaflets in most other species)
- dense tufts of rusty hairs at base of leaflets, but leaves otherwise hairless
- gap present between terminal bud and next lowest pair of lateral buds
- bark of younger trees very soft and corky
- samaras with wings extending around seed to base giving both ends a blunt appearance
- new twigs with purple lenticels; twigs hairless and rounded (vs. angled twigs of Blue Ash and hairy twigs of some forms of Red Ash).

Figure 1. Leaves, twigs and samaras of Black Ash (*Fraxinus nigra*. Note the 3-5 pairs of sessile leaflets per leaf, the broadly winged samaras rounded at both ends, and the gap between the terminal bud and nearest leaves (lower right). Photographs by Sean Blaney and David Mazerolle, AC CDC.

Figure 2. Bark of a young Black Ash (left) and a small Black Ash tree (right). The deeply ridged, soft-corky bark of young Black Ash trees, which is easily depressed with a fingertip, is distinctive. Photographs by Sean Blaney, AC CDC.

Population Spatial Structure and Variability

Black Ash is common over most of its Canadian range, with occurrences sparser at the western, northern and eastern peripheries. Distances among Canadian occurrences are generally less than 100 km, except for Newfoundland occurrences that are at least 230 km from Cape Breton occurrences (Figure 3). The isolation of Newfoundland occurrences may be significant in protecting them from Emerald Ash Borer (*Agrilus planipennis*) invasion.

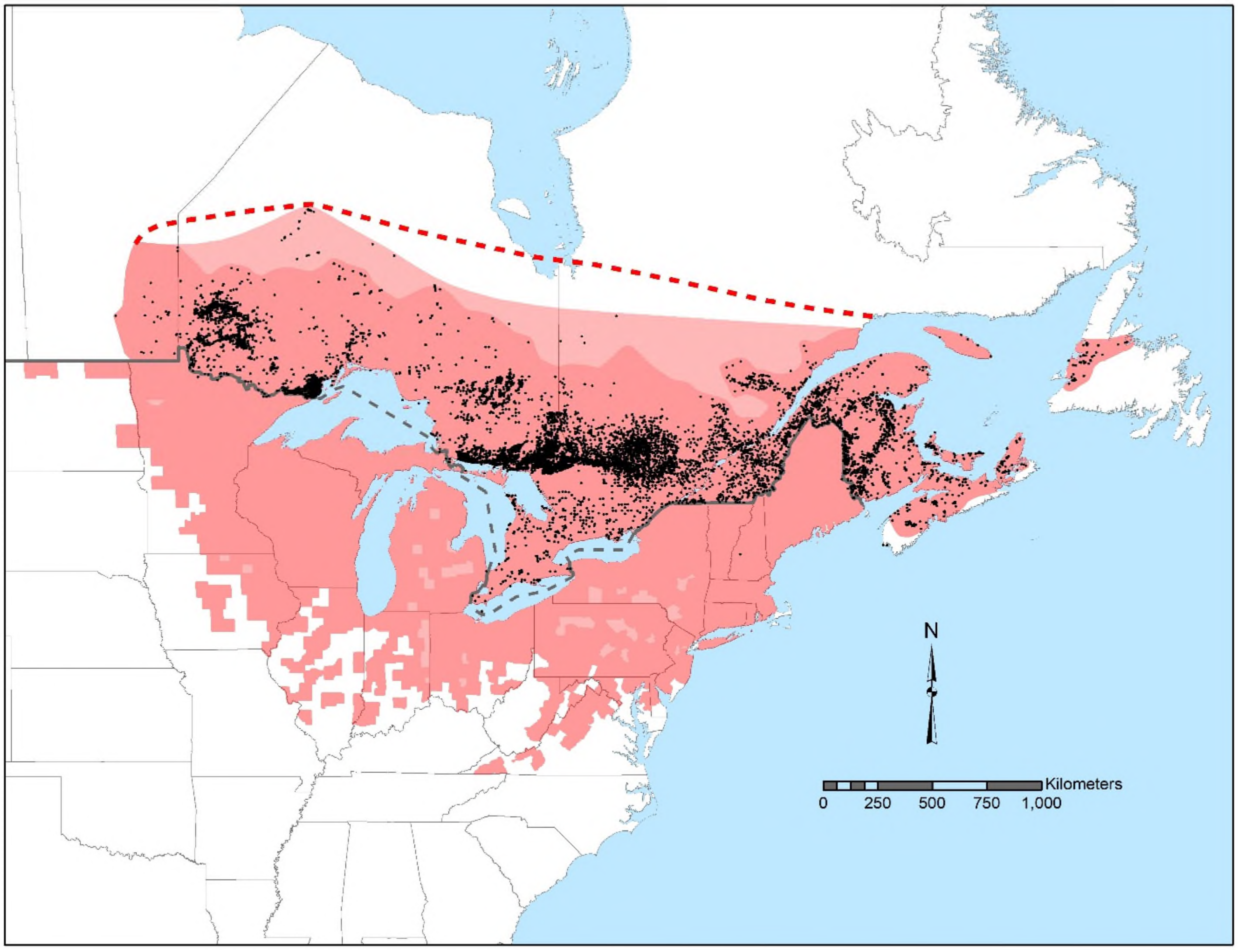

Figure 3. Global range of Black Ash, with geolocated occurrence records for Canada (black dots; see *Search Effort*). The United States range is modified from the county level distribution of Kartesz (2015) and the United States Forest Service (FIA 2016) with input from various state forestry employees contacted for this report. Pale shaded counties in the United States lacked documented occurrences but were considered part of the continuous range (Reznicek pers. comm. 2016). In Canada, the darker shaded area is based on published range maps (Farrar 1995; Watkins 2011), the lighter shaded area is a northern limit inferred from occurrence records and the hatched line indicates a potential maximum northern limit, based primarily on Baldwin (1958), who suggested occurrence north to 51.83ºN near James Bay.

There appears to have been limited investigation of genetic diversity in Black Ash. Compared to European Ash, relatively little sequence information is available in National Centre for Biotechnology Information (2017). Published work is limited to two main studies each of a limited geographic scale, described below.

Hendrickson (2012) investigated genetic diversity of Black and Red Ash in Minnesota. Out of 24 nuclear microsatellite markers originally developed from work on European Ash, she found five that successfully amplified and demonstrated Mendelian inheritance in Black Ash, and she sampled allele diversity of nine single tree seed lots (three with 31 seeds, six with 128 seeds) across those five markers. She found between two and 42 alleles per marker, with mean observed heterozygosity of 0.405 to 0.903 across the markers.

Simpson *et al*. (2008) investigated the genetic diversity of Black Ash from three sites in Nova Scotia, six sites in New Brunswick and adjacent Quebec and one in Manitoba (average 13 trees per site; 4.7 seeds per tree sampled across all sites). They analyzed allozyme variation at eight loci. Their study required seed, but they found a limited number of seed-bearing trees in Nova Scotia (one tree in Kejimkujik National Park, one tree from the adjacent Caledonia area, 12 trees from Oxford 180 km northwest), and therefore their inference of genetic structure in Nova Scotia subpopulations is limited. Across all their samples, and as is typical for wind-pollinated trees with relatively high rates of gene flow among subpopulations, they found weak evidence of genetic variation among subpopulations, with just 3.6% of the total genetic diversity resulting from differentiation between the sites. Total genetic diversity (H_T, measuring average frequency of heterozygosity over all loci and all sites) was 0.388, with an average within-subpopulation diversity (H_S) of 0.374. Heterozygosity was high, but was lower than expected at all sites, with the greatest difference at Oxford, Nova Scotia. Simpson *et al*. (2008) summarized their results as suggesting a loss of heterozygosity due to inbreeding at the Oxford site and noted that there was no evidence to suggest limiting the supplementation of Nova Scotian subpopulations with individuals derived from New Brunswick subpopulations.

Black Ash at a Cumberland County, Nova Scotia, site was reported to show morphological signs of hybridization (Hill-Forde 2004). If this truly represented hybridization, it would likely be with an introduced species as there is no known natural or artificial hybridization of Black Ash with co-occurring native species. The only documented hybrid involving Black Ash is an artificial cross with Manchurian Ash (and these produce limited, non-viable seed; see *Special Significance*). European Ash, in section *Fraxinus* (with Manchurian and Black Ash, Wallander 2013), may be a more likely hybrid parent because it is widely cultivated and fairly frequently established in the wild in Nova Scotia, whereas Manchurian Ash is not (Blaney and Mazerolle pers. obs. 1999-2017; AC CDC 2017).

Designatable Units

For this report no subpopulations are considered to meet the criteria for designation as separate DUs. Black Ash extends across three COSEWIC National Ecological Areas (Boreal, Great Lakes Plains, Atlantic) but distribution is relatively continuous within its range, and there are no recognized subspecific taxa of Black Ash.

There has been insufficient investigation of patterns of genetic diversity in Black Ash to suggest or refute genetic distinctiveness in any one region. Occurrences in Newfoundland represent the largest natural disjunction in Canada, being 230 km from those in northern Cape Breton, Nova Scotia, including 115 km across the Cabot Strait. This distance exceeds the species' expected normal pollen and seed dispersal distances (see *Dispersal and Migration*), meaning that genetic interchange between subpopulations across the Gulf of St. Lawrence is likely insufficient to prevent local adaptation. However, Newfoundland subpopulations are in climatic and ecological settings very similar to those in northern Cape Breton or eastern Quebec, such that there are likely no strong climatic drivers of local adaptation.

Special Significance

Black Ash has a significant ecological, ethnobotanical and cultural importance. Its wood is strongly ring-porous and highly pliable, making it ideal for basketry, barrel hoops, chair seats, snowshoe frames and canoe ribs (Benedict 2001; Benedict and Frelich 2008). The durable wood is valued commercially for tool handles, furniture, panelling, cabinets, door and window frames, interior finish and flooring (Forbes 2012; Beasley and Pijut 2013).

Indigenous peoples in Canada and the United States have used the species for centuries in the production of baskets, snowshoe framing and canoe ribs. Baskets are woven using thin flexible wood splints, which are produced by pounding a log with mallets until its annual growth rings separate (Benedict and David 2003). Black Ash basketry remains an important component of the histories, cultures and economies of many Indigenous peoples, including the Abenaki, Maliseet, Mi'kmaq, Mohawk, Ojibwe, Penobscot and Passamaquoddy (Smith 1928; Gilmore 1933; Speck and Dexter 1951, 1952; Rousseau 1947; Benedict and David 2000; Benedict 2001; Benedict and Frelich 2008).

The Indigenous peoples of central and eastern North America had many historical medicinal uses for Black Ash (Hoffman 1891; Smith 1923, 1928, 1932; Gilmore 1933; Speck and Dexter 1951, 1952; Hamel and Chiltoskey 1975; Herrick 1977). The Ojibwe are also reported to have produced a blue fabric dye from Black Ash bark (Gilmore 1933).

Black Ash is a foundational species in many wet forested ecosystems of central and eastern North America (Telander *et al*. 2015; Iverson *et al*. 2016; Youngquist *et al*. 2017). In riparian and wetland habitats where it can dominate the canopy, Black Ash is considered a climax species (Erdmann *et al*. 1987) and can play an important role in regulating hydrology through evapotranspiration (Slesak *et al*. 2014; Telander *et al*. 2015; van Grinsven *et al*. 2017), thereby maintaining suitable site conditions for associated tree, shrub and herbaceous species less tolerant to flooding (Lenhart *et al*. 2012). It is a dominant or co-dominant species in some swamp communities, in which it serves as an important source of food and shelter for large and small mammals, birds, arthropods, plants and fungi (see *Interspecific Interactions*).

The observed and projected decline of Black Ash will have substantial lasting impacts on the composition, structure and function of hydric ecosystems where the species is common (Beasley and Pijut 2013; DeSantis *et al*. 2013; Klooster *et al*. 2014; Wagner and Todd 2015; van Grinsven *et al*. 2017). Many ecosystems in which Black Ash is a major component have already been impoverished by the decline of American Elm (*Ulmus americana*) due to the introduced fungus responsible for Dutch Elm Disease (Brasier 1991).

As observed in Ohio, Indiana, Michigan and Minnesota, mass ash die-off can result in the conversion of riparian forest and swamp to open shrubland or graminoid meadow, with greater incidence of exotic invasive species such as Glossy Buckthorn (*Frangula alnus*) and Reed Canary Grass (*Phalaris arundinacea* subsp. *arundinaca*) (Palik *et al*. 2012; Wagner and Todd 2015). Other tree species with comparable flood tolerance may be limited in some areas, thus limiting canopy replacement.

Black Ash also provides important habitat for Flooded Jellyskin (*Leptogium rivulare*), a cyanolichen last assessed as Special Concern by COSEWIC (COSEWIC 2015b), but as of 2017 still listed as Threatened under the *Species at Risk Act*, and Canadian Sphinx (*Sphinx canadensis*), a hawk moth exclusively dependent upon Black Ash as a larval food plant in Canada (see *Interspecific Interactions*). Ten additional Black Ash-associated arthropods have been identified by Wagner and Todd (2015) as being moderately to highly threatened by ash decline. Nine of these ash-specialist species are known to occur in Canada.

Black Ash is widely available in the nursery trade but is much less commonly planted for landscaping than Red or White Ash. It has been subject to limited breeding and selection. The only commercially available named cultivar is 'Fallgold' (Santamour and McArdle 1983; Hill-Forde 2004; Google Patents 2017a,b). It is a seedless form with bright yellow fall foliage that is retained relatively late (Santamour and McArdle 1983). An unnamed cultivar developed in Minnesota and patented in the United States in 1975, and the cultivars 'Crispa' and 'Cucullata' developed in the 1800s in Europe (Santamour and McArdle 1983) are not available commercially. Black Ash can hybridize with Manchurian Ash (*Fraxinus mandshurica*) and cultivars are widely commercially available under the names 'Northern Treasure Ash' and 'Northern Gem Ash' (*Fraxinus nigra* × *Fraxinus mandshurica*, 'Northern Treasure' and 'Northern Gem'; Black Ash is the female parent). These hybrids and the 'Fallgold' cultivar were developed by Agriculture and Agri-Food Canada at Morden, Manitoba (Ronald 1976) and in 2001 each received United States patents, with the patent applications stating that the hybrids produce limited and non-viable seed (Google Patents 2017a, b).

DISTRIBUTION

Global Range

Black Ash is the most northern species of ash. Approximately 51% of the species' global range is within Canada[1]. Black Ash occurs from western Newfoundland to southeastern Manitoba and north-central North Dakota, ranging southward to Iowa, Illinois, Virginia and Delaware (Figure 3; Wright and Rauscher 1990; Kartesz 2015; FIA 2016; NatureServe 2017). A pre-1860 report from Fayette County, Kentucky mapped in Kartesz (2015) is considered potentially planted and the species is not listed as currently or historically present by the Kentucky Natural Heritage Program (Littlefield pers. comm. 2016). Black Ash reaches its northern limit in western Ontario near 53ºN, and its southern

[1] Calculated using United States county distribution and Canadian range polygons.

limit near 36.6ºN in southwestern Virginia (about 1700 km north to south), and it occurs between 56ºW in Newfoundland and 100ºW in North Dakota (about 3000 km east to west). Within this range, the species' distribution is fairly continuous from western Ontario to the Gaspé Peninsula, throughout the Great Lakes states, and from New Brunswick through New England south to New Jersey.

A significant portion of available occurrence data predates the impact of Emerald Ash Borer in North America. Where peripheral occurrences overlap with highly infested regions, as in much of the Midwest United States and southwestern Ontario, local extirpation may have occurred within some areas represented as occupied in Figure 3, especially where Black Ash habitat and occurrence were already reduced by extensive conversion to agriculture.

Canadian Range

Within Canada, Black Ash occurs from western Newfoundland in the east to southeastern Manitoba in the west (Figure 3). Though uncommon and sparsely scattered near the margins of its range, its distribution is relatively continuous within the Atlantic and Great Lakes Plains National Ecological Areas and into the Boreal National Ecological Area. Its northern limits are not precisely documented throughout the boreal forest, but it is known to occur north to approximately 50.2ºN in Quebec and 53ºN in Ontario. Range information in this report is from maps in Farrar (1995) and OMNR (2011), supplemented with occurrence data from a wide variety of sources outlined below under *Search Effort*.

In Newfoundland, Black Ash is rare and limited to a small portion of the island, mainly along its central western coast. Forming a rough triangle, the species' range extends from the head of St. George's Bay in the south to Bonne Bay in the north and Springdale in the northeast. Much of the provincial range coincides with the presence of underlying Ordovician, Devonian and Carboniferous bedrock with high pH (Colman-Sadd *et al*. 1990).

Black Ash on Anticosti Island, Quebec, is mentioned in historical documents as localized or locally common (Despecher 1895; Schmitt 1904; Marie-Victorin 1935), but the actual extent of its distribution on the island is not well known and its frequency may have been reduced by introduced White-tailed Deer, *Odocoileus virginianus* (see *Threats*). Specimens collected as recently as 1974 document occurrences in riparian forest along the lower sections of Rivière aux Saumons and the Rivière Vauréal (Canadensys 2016), but Anticosti Island botanist Danièle Morin knows only of single trees on Rivière aux Saumons and Rivière Observation (Tremblay pers. comm. 2017).

Black Ash is widespread in the Atlantic National Ecological Area, and common to abundant in northern and western New Brunswick and the Bas Saint-Laurent region of Quebec but is uncommon and thinly scattered in southeastern New Brunswick, Nova Scotia, Prince Edward Island and the northeastern Gaspé Peninsula. In Nova Scotia, the species' range appears to have declined since 1958 (see *Threats – Unidentified Disease or Insect*) and it is not known from much of the southern and eastern regions where strongly acidic soils predominate. Recent Black Ash records from these areas tend to be European

Ash (*Fraxinus excelsior*; Blaney and Mazerolle pers. obs. 2000-2016), and for this report a few unverifiable occurrences reported from atypical habitats and regions for Black Ash have been presumed to represent European Ash.

In Quebec, Black Ash ranges north to the Matagami area near James Bay (50.2ºN) in the northwest and to at least 49ºN in the Côte-Nord region. In Ontario, the species is documented north to the Albany River and Moose River drainages near James Bay (Riley 2003), with the northernmost specific occurrence documented near 52.9ºN along the Pipestone River, District of Kenora.

In Manitoba, the species is uncommon and restricted to the province's southeast corner, reaching its northeastern limit just north of Atikaki Provincial Park and its northwestern limit near Lake Winnipeg's Fisher Bay. An occurrence approximately 70 km northwest of Winnipeg (-97.75ºW) represents the westernmost edge of Black Ash range in Canada.

Aboriginal Traditional Knowledge (ATK) distribution information is not publicly available from most communities within the species' distribution (COSEWIC ATK Subcommittee 2015). ATK sources (e.g., Hill-Forde 2004; Black River First Nation 2005; Roberts 2005; CEPI 2006; Stoney Point First Nation 2006; Benedict and Frelich 2008; Mi'kmaq Confederacy of Prince Edward Island 2014) report no occurrences that are outside the distribution reported in scientific literature, although many ATK reports have not been recently updated and information is not available from Newfoundland.

Interspecific hybrids involving Black Ash and planted Black Ash outside the native range are not considered part of the population under assessment in this report (COSEWIC 2010). Reproductive planted Black Ash within the natural range are considered part of the population (COSEWIC 2010) but are believed to represent a trivial portion of the total population.

Extent of Occurrence and Area of Occupancy

The extent of occurrence of Black Ash in Canada, calculated using the standard COSEWIC minimum area convex polygon method (COSEWIC 2015a) applied to the dataset of occurrences compiled for this report, with area south of the Canadian border excluded, produces a value of 2,004,000 km^2.

As outlined above under *Canadian Range*, the occurrence dataset (Figure 3) compiled for this report is known to be very incomplete, meaning there is little value in calculating index of area of occupancy (IAO) by overlapping that occurrence dataset with a 2 km x 2 km grid. We can roughly estimate the IAO using the polygons forming the mapped Canadian range in Figure 3. Collectively those polygons, with 79,500 km^2 of open water area removed, amount to 1,186,400 km^2 (roughly 296,600 2 km x 2 km grid boxes). In much of that area, Black Ash is common enough that it would occur in a high proportion of 2 km x 2 km boxes covered by the range (see, for example, the southern margin of northern Ontario in Figure 3). IAO is thus a significant portion of the 1,186,400 km^2

Canadian range and well above threshold values relevant to status assessment. It is roughly estimated here as 500,000 km^2.

Search Effort

No fieldwork was carried out specifically for the preparation of this status report, because the limited field time permitted by available funding would not have substantially increased knowledge of the range-wide distribution, abundance or status of such a widespread species.

Black Ash is still considered a common species in Ontario, Quebec and New Brunswick so detailed occurrence information has generally not been recorded during botanical fieldwork in those provinces and there had been no systematic effort to compile available occurrence data prior to this report. For this report a dataset of roughly 25,000 occurrences[2] was compiled from the following sources: Baldwin (1958), Rousseau (1974), Riley (2003), Atlantic Canada Conservation Data Centre (AC CDC 2017), New Brunswick Department of Energy and Resource Development (NBDERD 2016), the New Brunswick Museum (NBM 2016), the Connell Memorial Herbarium (CMH 2016), Quebec Ministère des Forêts, de la Faune et des Parcs (MFFPQ 2016), the Ontario Natural Heritage Information Centre (ONHIC 2016), Ontario Ministry of Natural Resources and Forestry (OMNRF 2016a, b; OFRI 2017; OPIAM 2017), the Manitoba Conservation Data Centre (MCDC 2016), the Canadian Forest Service (CFS 2016) and Canadensys (2016).

Aside from some uncertainties about the northern margin of the range (see *Canadian Range*), the above dataset outlines Black Ash range in Canada fairly well but is highly incomplete relative to the actual occurrence on the ground (Blaney and Mazerolle pers. obs. 1999-2017; Oldham pers. comm. 2017). Because Black Ash is still common over most of its extensive Canadian range, there are clearly many thousands of undocumented occurrences and hundreds or more documented occurrences from various herbaria, local plant lists or personal observations that were not compiled for this report.

In Manitoba, Prince Edward Island, Nova Scotia and Newfoundland, where Black Ash is tracked as a naturally uncommon to rare species, occurrence data have been more systematically compiled and represent a greater proportion of actual occurrences. In all of these jurisdictions there are still unsearched suitable habitats with high potential for additional occurrences. In Prince Edward Island and Nova Scotia, new occurrences are documented every year, although these generally do not represent large populations with healthy reproductive individuals (AC CDC 2017).

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[2] Including a small proportion of OMNRF plot records along the southern margin of northern Ontario that were reported as “ash species” and could be Red or White Ash.

HABITAT

Habitat Requirements

Extensive documentation of Black Ash habitat and associated species and communities are found in Erdmann *et al*. (1987), Wright and Rauscher (1990), Gucker (2005) and Ehrenfeld (2012). Unless otherwise noted, habitat description is from these sources. Black Ash is classified as a facultative wetland or facultative wetland+ species throughout its range (meaning that an estimated 66% to 99% of all occurrences will be in wetlands; Ehrenfeld 2012; Lichvar *et al*. 2016). It occurs most frequently in floodplain forests, basin, seepage and lacustrine swamp forests, shoreline forest margins, and fens. Reports of frequent occurrence in bogs (e.g., Gates 1942; Wright and Rauscher 1990; Runesson 2017) generally refer to at least moderately minerotrophic sites more accurately called fens (i.e. Janssen 1984; Gucker 2005). Occupied habitats are often seasonally flooded (Erdmann *et al*. 1987), where the flood tolerance of Black Ash offers a competitive advantage over more common species that are faster growing or more tolerant of nutrient-limitation, fire or other stresses (Erdman *et al*. 1987; Tardif and Bergeron 1992, 1999; Denneler *et al*. 1999, 2008).

Black Ash can grow on a variety of soil types. It is frequent on finer alluvial and peat and muck soils but is also documented on clayey loam, fine sands underlain by sandy till, and sands and loams underlain by lake-washed clayey till (as summarized in Gucker 2005). Black Ash is tolerant of a wide range of pH conditions, from 4.4 to 8.2 (Godman and Mattson 1976) but is generally more abundant in moderately to strongly alkaline and nutrient-rich soils (Heinselman 1970; Hosie 1979; Brand 1985; Kurmis *et al*. 1986; Zogg and Barnes 1995; Loo and Ives 2003; AC CDC 2017). Frequently associated tree species in the more northern parts of its range, where it is commonly in mixed deciduous-conifer or conifer-dominated swamps, include Black Spruce (*Picea mariana*), Tamarack (*Larix laricina*), Balsam Fir (*Abies balsamea*), Speckled Alder (*Alnus incana* ssp. *rugosa*), Eastern White Cedar (*Thuja occidentalis*), White Spruce (*Picea glauca*), Red Maple (*Acer rubrum*) and Balsam Poplar (*Populus balsamifera*). In the southern parts of Ontario, Quebec and New Brunswick, Black Ash occurs most frequently in deciduous or Eastern White Cedar swamps and may be associated with American Elm (*Ulmus americana*), Silver Maple (*Acer saccharinum*), Red Ash, Red Maple, Basswood (*Tilia americana*) and Bur Oak (*Quercus macrocarpa*). Black Ash also occurs widely in upland forests, often in locally moist microsites, where it is generally an uncommon to rare species, with Sugar Maple (*Acer saccharum*), Yellow Birch (*Betula alleghaniensis*) and/or Eastern Hemlock (*Tsuga canadensis*) being among the dominants.

Further discussion of response to varying light and water levels is given under *Physiology and Adaptability*.

Habitat Trends

Black Ash habitat has been extensively lost to habitat conversion since 1837, three generations (180 years) in the past, primarily in the Great Lakes Plains National Ecological

Area, which represents 8.9% of Black Ash range in Canada (112,900 km^2 out of 1,265,900 km^2, based on the range represented in Figure 3 and COSEWIC 2015a).

A careful and comprehensive analysis by Ducks Unlimited (2010), calculated that 72% of wetlands greater than 10 ha had been lost within southern Ontario's Mixedwood Plains ecosystem (nearly identical to the Ontario portion of the Great Lakes Plains National Ecological Area), from pre-settlement to 2002. Almost all of this wetland loss would post-date 1837 (three Black Ash generations in the past; when Upper Canada had a human population of 397,489 vs. 2.5 million in 1911 after farming settlement of the Great Lakes Plains was largely complete; Statistics Canada 2017a,b). Not all wetlands in southern Ontario would have contained Black Ash historically, but there is no reason to believe that wetlands containing Black Ash would have been less affected by the above loss than other wetlands. Assuming the 72% wetland loss applies to Black Ash habitat throughout the Great Lakes Plains, this would translate to 6.4% habitat loss in Canada (72% of the 8.9% of Canadian Black Ash range that is within the Great Lakes Plains). Actual loss of Black Ash habitat to conversion would be higher than this because: 1) Although a much smaller proportion of the landscape has been converted to human use in the Boreal and Atlantic National Ecological Areas, some major habitat conversion has also taken place in those regions, associated especially with hydroelectric dams throughout and with agriculture in Atlantic Canada; 2) Conversion of wetlands smaller than 10 ha in the Great Lakes Plains would have resulted in substantial additional loss of Black Ash; 3) Although most Black Ash is in wetlands, the species does occur in uplands, where habitat conversion has also been substantial in the Great Lakes Plains and elsewhere; 4) Certain aspects of the methodology in Ducks Unlimited (2010) underestimate actual conversion (i.e. areas flooded by large dams would not have been considered wetland loss, classification of bottomland soils was uneven across the study area, some Great Lakes shoreline wetlands were not included in the study; Ducks Unlimited 2010); and 5) Habitat conversion has continued since 2002. Wetland loss in the Mixedwood Plains since 2002 could not be calculated in Ducks Unlimited (2010), but between 1982 and 2002 it was estimated at 3.5% loss of wetlands or 0.175% per year (0.016% of the Canadian range of Black Ash per year). Rate of current habitat loss in the Mixedwood Plains is likely lower because of stronger wetland protection policies. Habitat loss also continues outside the Mixedwood Plains, with conversion to plantation forestry being one of the largest factors (see *Threats – Wood and Pulp Plantations*), but this is harder to quantify and likely on a much smaller scale than past conversion. Even over a long period (60 years – one generation), habitat loss at the current rate seems unlikely to compound to a level exceeding 15% nationally.

Flooding from hydroelectric dams is another relatively significant factor that has reduced Black Ash habitat in the past two to three generations, given the species' association with floodplains and shorelines. Ontario, Quebec and New Brunswick, representing most of the Canadian range of Black Ash, collectively have 455 large dams (≥15 m in height) built for hydroelectric power generation, water supply, or other uses (Lee *et al.* 2012). With the exception of Quebec's large dams in the James Bay and Hudson Bay drainages, almost all of these dams are within the Canadian range of Black Ash. Many hundreds or thousands of smaller unregistered dams are also present within Black Ash range. Existing large dam reservoirs have flooded 31,575 km^2 in those three provinces (Lee *et al.* 2012) probably representing thousands of km^2 of former Black Ash habitat in Canada (some of which would have already been unsuitable due to earlier habitat conversion for agriculture). Increased demand for renewable energy may drive further development of large hydroelectric dams within Black Ash range in the future (Canadian Hydropower Association 2017), but this is unlikely to affect a large portion of the species' habitat.

Artificial flooding has been and continues to be a significant influence on Aboriginal traditional uses of Black Ash, because most Aboriginal communities are located at or near waterways and historically the most readily accessible and transportable stands of Black Ash would have been found along waterways (Ballard pers. comm. 2017).

BIOLOGY

Life Cycle and Reproduction

Black Ash can flower at about 30-40 years of age (Heinselman 1981) when stems reach 8 cm in diameter at breast height (Wright 1953). The small wind-pollinated flowers of Black Ash emerge in late May to early June, concurrently with or just before leaf emergence (Wright 1953; Wright and Rauscher 1990; Benedict and David 2003). Black Ash is generally polygamous (both unisexual and bisexual flowers borne on the same tree), but some trees may be solely male or female (Bonner 1974). The winged single-seeded samaras mature from July to September or October and are dispersed from early fall throughout the winter until early spring (Schopmeyer 1974; Erdmann *et al*. 1987; Lees and West 1988; Wright and Rauscher 1990; Wright and Rauscher 1990). Good mast production occurs at irregular intervals of one to eight years (Bonner 1974; Godman and Mattson 1976; Erdmann *et al*. 1987; Sims *et al*. 1990). Over 25 years, Godman and Mattson (1976) found that high Black Ash seed production (61% to 100% of maximum crop) occurred in 28% of years and low seed production (less than 36% of maximum crop) occurred in 68% of years. Large, healthy trees would have the potential to produce thousands of seeds in a good seed year, as they would have hundreds of inflorescences, each with potential to produce 20 or more seeds. Average seed viability within the Canadian population can vary considerably between collection sites and averaged roughly 62% in a Canadian Forest Service study (NTSC 2016). Simpson *et al*. (2008) found that seed viability was relatively low (28%) in Nova Scotian seeds, which may be a consequence of generally poor tree health observed in the province (Blaney and Mazerolle pers. obs. 1999-2017).

Black Ash seeds exhibit deep physiological dormancy and require a process of natural stratification and after-ripening involving exposure to moisture and both high and low temperatures (details given under *Physiology and Adaptability*). Ash seed banks are relatively short lived, which may limit ability to recover from stand mortality. Black Ash and other ash seeds are reported to retain viability in the soil from three to eight years (Sims *et al*. 1990; Wright and Rauscher 1990; BenDor *et al*. 2006), but Klooster *et al*. (2014) found complete loss of the soil seed bank (500,000 seeds/ha to 0) within three years in ash stands being killed by Emerald Ash Borer, suggesting that few seeds remain viable as long as eight years. Seeds are capable of germinating in leaf litter or in soil depths of up to 2 cm

(Erdmann *et al*. 1987). First year seedlings may reach a height of over 15 cm (Erdmann *et al*. 1987). Although they undergo relatively rapid early growth (Carmean 1978), seedlings remain poor competitors and must overcome competition from other understory vegetation in order to successfully establish.

Black Ash readily sprouts from adventitious buds on root crowns, roots and stumps (Erdmann *et al*. 1987; USDA NRCS 2006), especially following fire, browsing or cutting (Gucker 2005). Cut stems may produce up to 17 vigorously growing sprouts (Lees and West 1988). For the purposes of COSEWIC assessment, resprouting from cut stumps or root crowns is not reproduction because the resulting units could not be physically separated from the mature individual under natural conditions and would be unlikely to survive on their own if they were separated. Sprouting from roots at some distance from an existing trunk would be classified as reproduction if the unit ultimately developed sufficient roots of its own to survive if the connecting root died, but this has not been noted in the literature or in the field (Blaney and Mazerolle pers. obs. 1999-2017). Literature references to “vegetative reproduction” in Black Ash refer to re-sprouting from cut or broken stumps or from the root collar. Trial and Devine (1994) found that 69.4% of regeneration in Maine was through sprouting and only 13.5% from seed. In northern Quebec, Tardif and Bergeron (1992, 1999) determined that saplings generated from seed are more common and faster growing than vegetative sprouts on well-drained sites, while the reverse occurs on sites exposed to flooding. The faster height and diameter growth rates of vegetative sprouts in hydric habitats is likely due to an increased flood tolerance conferred by their more developed root systems (Tardif and Bergeron 1999).

Physiology and Adaptability

Black Ash is generally described as a relatively slow-growing tree, exhibiting growth rates of 45 to 75 cm/year, which are commonly exceeded by associated species (Carmean 1978; Erdmann *et al*. 1987; USDA NRCS 2006; Wright and Rauscher 1990). Growth rates are largely dictated by competition (Stewart and Krajicek 1978; Benedict and Frelich 2008; Forbes 2012), hydrology, and climate (Tardif and Bergeron 1993; 1997). Erdmann *et al*. (1987) report diameter at breast height of 25 cm at 110 years and 30 cm at 130 years in organic peat and muck, where high water tables and frequent flooding disturbance limit growth potential (Wright and Rauscher 1990; Benedict and Frelich 2008). On well-drained sites, when not hindered by faster growing competitors, Black Ash can exhibit rapid early height growth (9 to 13 m in 50 years; Levy 1970; Carmean 1978).

The largest individuals are known from the southern parts of the range (Iowa and Ohio, see *Morphological Description*) with the longest growing season. Black Ash may be especially limited by short growing seasons because it is one of the last tree species to leaf out and the first to lose its leaves (Ahlgren 1957). The species grows in a fairly wide range of mesic to wet mineral or organic soils and can tolerate moderately acidic to strongly alkaline substrates but is most frequent in more alkaline conditions (see *Habitat*). Black Ash leaves have more calcium, magnesium, nitrogen, and ash than many other hardwoods (Reiners and Reiners 1970), which may relate to association with alkalinity.

Black Ash is most frequent in very wet habitats because it is among the few tree species well-adapted to tolerate seasonal flooding in near-stagnant standing water (Erdmann *et al*. 1987). Tardif and Bergeron (1999) note that yearly flooding events in a riparian Black Ash stand lasted an average of 24 days, with some events lasting up to 65 days. Although seedlings require periods free of prolonged flooding to establish, vegetative sprouting can occur regardless and ensure regeneration (Tardif and Bergeron 1992, 1999).

Black Ash is a moderately shade-tolerant, mid- to late-successional tree that commonly constitutes a climax species in poorly drained soils (Gucker 2005). Its seedlings reportedly exhibit a greater tolerance of shade than those of associated species such as Yellow Birch (*Betula alleghaniensis*) and American Elm (*Ulmus americana*) but become more intolerant with age (Erdmann *et al*. 1987). Erdmann *et al*. (1987) suggest that seedlings develop best in conditions of 45 to 50 percent full sunlight.

Black Ash is a shallow-rooted tree, particularly when in hydric soils susceptible to flooding, making it especially prone to windthrow (Erdmann *et al*. 1987; USDA NRCS 2006). It is also fire-sensitive and may be top-killed by even moderate-severity fires (Heinselman 1981; Grimm 1984). In healthy populations, however, Black Ash can regenerate quickly following fire, windthrow or cutting (Heinselman 1981; Lees and West 1988; Arévalo *et al*. 2000; Gucker 2005) and quickly colonizes natural or human-caused gaps in northern hardwood swamp communities (Erdmann *et al*. 1987). There is also some evidence of mass establishment in wetland (Gates 1942) and upland or borderline upland communities following fire (i.e. young post-fire Paper Birch (*Betula papyrifera*) - aspen (*Populus* spp.) - White Spruce stands on Isle Royale, Michigan, Hansen *et al*. 1973), or wind storms (Arévalo *et al*. 2000). Black Ash thus could be considered relatively opportunistic and resilient to disturbance (Gucker 2005).

Seeds exhibit deep physiological dormancy, with embryos that are immature when the seed is shed. A first level of dormancy is broken by exposure to high summer temperatures near 20°C, which trigger embryo growth (Steinbauer 1937; Vanstone and LaCroix 1975; Benedict and David 2003). Seeds must then be subjected to moist cool conditions in autumn, winter and early spring to break a second level of dormancy (Baskin and Baskin 1998; Benedict and David 2003; Simpson pers. comm. 2016, who recommends 60 days of moist chilling at 4°C, 120 days of moist incubation at 21°C, then 180 days of moist chilling at 4°C). During a period of at least 2 months of cold stratification, the embryo utilizes reserves from the endosperm and later breaks the seed coat in spring when warmer temperatures return (Steinbauer 1987; Simpson pers. comm. 2016). Under natural conditions, seeds thus generally take at least 1.5 years to germinate, only fully overcoming dormancy in the second spring after seed fall or later. Germination requirements may play a significant role in northern and southern range limits (Morin *et al*. 2007). Good seed viability may be maintained in controlled environments for over 15 years, meaning that ex situ seed banking for use in research, conservation and restoration efforts is feasible (Smith *et al*. 2000). Adventitious shoot regeneration and rooting procedures have also been developed (Beasley and Pijut 2010).

Elevation tolerance is not widely reported for Black Ash, but occurrence from sea level is known in the northern parts of Black Ash range, and it is restricted to elevations above 610 m at the southern range edge (Wright and Rauscher 1990; AC CDC 2017). Kudish (1992) indicated occurrence at 31 m to 853 m in New York's Adirondack Mountains.

Dispersal and Migration

Black Ash is wind-pollinated and its winged samaras promote wind dispersal (Erdmann *et al*. 1987; Wright and Rauscher 1990; Sutherland *et al*. 2000). The wing of the samara causes autorotation as it falls, thereby reducing the sinking speed and increasing distance transported by winds (Norberg 1973). Bacles *et al*. (2006) found documented seed dispersal up to 1.4 km in European Ash and estimated that seed dispersal was up to six times more effective than pollen dispersal in maintaining genetic connectivity among remnant stands. Pollen dispersal for Black Ash can be inferred to exceed 1 km based on other wind-pollinated temperate tree species (Sork and Smouse 2006; Craft and Ashley 2007). These properties are in general agreement with the findings of low genetic differentiation among populations found by Simpson *et al*. (2008).

Ash species generally have fruits that float well, and water dispersal over the scale of kilometres is well documented (Thébaud and Debussche 1991; Schmeidel and Tackenberg 2013). Large numbers of Black Ash samaras are often visible in the wrack lines of rivers that support large populations, and seedlings are often abundant in recently deposited alluvial soils in northern and western New Brunswick (Blaney and Mazerolle pers. obs. 1999-2017). The broader-winged fruits of Black Ash (vs. Red or White Ash) with their blunter proximal ends, may be trading water floatation potential against wind-dispersal potential. During spring freshet and other high-water events, samaras would be carried downstream over considerable distances. In France, the adventive Manna Ash (*Fraxinus ornus*) showed an average yearly spread of nearly 1 km in riparian habitats via water-dispersal of samaras (Thébaud and Debussche 1991). Fruits of tree species such as American Beech (*Fagus grandifolia*) and Eastern Hemlock (*Tsuga canadensis*) are known to be carried by water across the Great Lakes (Davis *et al*. 1986). The fruits of Black Ash, which appear much better adapted for water dispersal than the above species, are likely capable of similar cross-lake dispersal, especially in cases where samaras are dispersed as a whole inflorescence attached to a branch fragment that would increase floatation (a regular phenomenon, Blaney pers. obs. 1989-2017). In Red Ash, mean samara floatation time under laboratory conditions was two days, and storage in water for 15 days significantly increased subsequent germination (Schmeidel and Tackenberg 2013). Large numbers of Black Ash fruits can remain on trees and continue to disperse into early winter (Curtis 1959; Blaney and Mazerolle pers. obs. 1999-2017). Under the right conditions they can be quickly blown across open ice of lakes and rivers. Curtis (1959) called the winter-shed fruits "ice boats".

Small seed-caching rodents, including squirrels and chipmunks (family Sciuridae), which aggressively seek out tree seeds, are likely important dispersal vectors over short distances (Moore *et al*. 2007) and waterfowl may effectively contribute to long-distance dispersal (COSEWIC 2014).

As a highly culturally significant species, Black Ash may have been deliberately dispersed by First Nations in historical times (see review in MacDougall 2003). Current horticultural and ecological/cultural restoration plantings by First Nations (i.e. Benedict 2011; Kershner 2015; Julien 2017) and others continue to influence distribution today.

Interspecific Interactions

The biology of Emerald Ash Borer is discussed under *Threats*.

Black Ash is host to a diverse fauna. Gandhi and Herms (2010) found literature documenting 43 native North American arthropods in six taxonomic groups (mites - Acari, beetles - Coleoptera, flies - Diptera, true bugs - Hemiptera, wasps and relatives - Hymenoptera and butterflies and moths - Lepidoptera), known to be exclusively associated with ash trees for either feeding or reproduction. In order of frequency, these are gall-forming species, folivores, subcortical feeders, sap feeders and seed predators. Orders with the highest numbers of ash-associated monophagous species are Diptera (11 species), Coloeptera (nine species), Lepidoptera (nine species) and Hemiptera (eight species). The same study identifies another 30 arthropods that are only associated with one or two host species in addition to ash.

In an assessment of the ecological repercussions of ash decline due to Emerald Ash Borer, Wagner and Todd (2015) identified 11 ash specialist herbivores associated with Black Ash, assigning an endangerment risk to each species based on host-specificity. Canadian Sphinx hawkmoth (*Sphinx canadensis*; Sphingidae) appears particularly threatened by Black Ash decline. Canadian Sphinx caterpillars show a marked preference for young shaded Black Ash individuals (Tuttle 2007; Handfield 2011). The northern range of this species closely follows that of Black Ash and it is reported as highly host-specific to Black Ash in Quebec, New Brunswick, Maine, Indiana and Michigan, even in sites where other ashes occur in close proximity (Tuttle 2007; Handfield 2011; Wagner and Todd 2015). Although it is presently ranked as nationally Secure (N4), predicted decline of Black Ash in Canada will undoubtedly impact the Canadian Sphinx population and possibly its range. Remaining Black Ash-associated arthropods identified by Wagner and Todd (2015) are also commonly found on White Ash, Red Ash, or both. Of these species, six are highly threatened by ash decline (the leaf-mining moth *Caloptilia fraxinella* [Gracillariidae], the sawfly *Eupareophora parca* [Tenthredinidae], the owlet moths *Papaipema furcata* and *Sympistis chionanthi* [Noctuidae], the snout moth *Palpita magniferalis* [Pyralidae], and the aphid *Prociphilus fraxinifolii* [Aphididae]). Four are moderately to highly threatened (the sphinx moths *Ceratomia undulosa* and *Sphinx kalmiae* [Sphingidae], and the weevils *Lignyodes bischoffi* and *Lignyodes helvolus* [Curculionidae]).

Black Ash is known to provide important substrate for Flooded Jellyskin Lichen (*Leptogium rivulare*), a small boreal-temperate foliose cyanolichen only known in North America from a limited number of sites in Manitoba, Ontario and southern Quebec (COSEWIC 2015b). Flooded Jellyskin is mainly found in calcareous forested vernal ponds fringed by flood-tolerant trees. Its status was revised to Special Concern by COSEWIC in

2015 but it is still listed as a Threatened species under the federal *Species at Risk Act* (SARA). Although it can grow on a variety of substrates in its preferred habitat, most of the known Canadian population occurs on the bark of Black Ash and Red Ash trees (COSEWIC 2015b). Ash decline due to Emerald Ash Borer is therefore considered one of the foremost threats to this species at risk (Environment Canada 2013).

Small rodents such as squirrels (*Sciurus* spp., *Tamiasciurus hudsonicus*), chipmunks (*Tamias* spp.) and mice (*Peromyscus* and other genera), in addition to beaver and Porcupine (*Erethizon dorsatus*), will feed on ash samaras, as do many birds including Ruffed Grouse (*Bonasa umbellus*), Wild Turkey (*Meleagris gallopavo*), Bobwhite (*Colinus virginianus*), Wood Duck (*Aix sponsa*) and songbirds including Northern Cardinal (*Cardinalis cardinalis*), chickadees (*Poecile atricapillus*, *P. carolinensis*), Purple Finch (*Haemorhous purpureus*) and Pine Grosbeak (*Pinicola enucleator*) (Martin *et al*. 1951; Dickerson 2002, 2006; Wagner and Todd 2015). At the western edge of its range in southeastern Manitoba, Black Ash is the dominant canopy tree in high quality riparian forests that support at least seven provincially rare or uncommon understory species with eastern North American affinity (Kornelson and Hamel 2015).

White-tailed Deer and Moose (*Alces americanus*) commonly browse Black Ash branches, twigs, seedlings and sprouts (Elias 1987; Erdmann *et al*. 1987; Wright and Rauscher 1990). Snowshoe Hare (*Lepus americanus*) and American Beaver (*Castor canadensis*) also feed on non-woody tissue (de Vos 1964; Johnston and Naiman 1990). Studies indicate that healthy Black Ash can generally tolerate heavy browsing (Aldous 1952; Erdmann *et al*. 1987). Aldous (1952) simulated continuous moderate and heavy deer browsing in a six year study within a deer and Snowshoe Hare exclosure in Minnesota, finding that Black Ash greatly increased number of twigs, length of twigs, and total biomass production in response to clipping.

By virtue of its occurrence as a dominant or co-dominant tree, Black Ash is an important source of food and shelter for wildlife. Although no vascular plants or vertebrates are known to rely exclusively on Black Ash, a wide range of organisms are locally dependent on it as a defining element of the forested ecosystems in which they live. In ecosystems where it is dominant, Black Ash can be considered a foundation species (*sensu* Dayton 1972), creating and maintaining suitable habitat for associated flora and fauna (see *Significance*). The widespread mortality and local extinction of Black Ash could therefore have significant impact on local biota, forest structure, hydrology and other core ecological attributes of Black Ash bottomlands and swamps (Lenhart *et al*. 2012; Telander *et al*. 2015; Wagner and Todd 2015). Loss of Black Ash could also have indirect ecological consequences, as herbivore populations formerly dependent on ash as a primary food source move to other available species. Mass fatality of mature trees from Emerald Ash Borer infestations can result in long-term changes to forest composition (Hoven *et al*. 2014) as well as influx of exotic invasive plants (Palik *et al*. 2012; Wagner and Todd 2015) and animal species adapted to disturbed areas (Matsuoka *et al*. 2001; Tingley *et al*. 2002).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

No fieldwork was carried out specifically for the preparation of this status report, because the limited field time permitted by available funding would not have substantially increased knowledge of the rangewide distribution, abundance or status in such a widespread species. The data sources behind the occurrence dataset compiled for this report are listed under *Search Effort*.

Abundance

The Canadian population of Black Ash was estimated in Blaney *et al*. (2018) as 162,430,465 mature individuals (diameter at breast height of 10 cm or more), with 51.0% in Ontario, 43.9% in Quebec, 5.1% in New Brunswick and <1% in other provinces. Derivation of the values is fully described in Blaney *et al*. (2018) and summarized by province below.

1) New Brunswick: A direct estimate of 8,300,000 individuals over 10 cm diameter (New Brunswick Department of Energy and Resource Development, unpublished analysis of data from Forest Development Surveys 2003-2012; Sabine pers. comm. 2017);
2) Quebec: Timber volume data (MFFPQ 2018) converted using a ratio of number of individuals over 10 cm diameter to volume derived from 181,932 Quebec forestry plots. This estimates the Quebec population at 71,321,192;
3) Ontario: Timber volume data (OMNRF, from Watkins pers. comm. 2018), corrected to account for lumping of all ash species in southern Ontario and for lumping of ash into "other hardwoods" in certain areas of northern Ontario, and converted using the Quebec individuals:volume ratio described above. This estimates the Ontario population at 82,809,273.

The Canadian population estimate above does not include numbers from Manitoba, Nova Scotia, Prince Edward Island and Newfoundland. For the latter three provinces numbers are known to be small enough to be trivial relative to the national population (AC CDC 2017). Numbers in Manitoba could be into the hundreds of thousands if densities similar to those recorded in adjacent western Ontario (OMNRF data from Watkins pers. comm. 2018; see Blaney *et al*. 2018) occur over much of the Manitoba range, but this would still represent well below 1% of the Canadian total. The Canadian population estimate above also does not include occurrence north of commercial forestry where provincial forestry information is lacking (roughly equivalent to pale shaded areas in Figure 3; see Blaney *et al*. 2018). Numbers within this area cannot be easily estimated, but they too probably represent a small portion of the national population because Black Ash is generally restricted to larger river valleys and occurs at very low densities along the northern margins of the range (Harris pers. comm. 2017; Oldham pers. comm. 2017; Uhlig pers. comm. 2017).

Fluctuations and Trends

There is little quantitative assessment of fluctuations or trends in the Canadian Black Ash population. As a long-lived organism (maturity around 30 years, potential longevity well over 200 years - see *Life Cycle and Reproduction*), it is not expected to exhibit significant short-term fluctuations in total population of mature individuals or range, although significant local subpopulation increases have been documented in the Great Lakes states following forest fire (Hansen *et al*. 1973) and windthrow disturbance (Arévalo *et al*. 2000).

Emerald Ash Borer is now the most significant driver of Black Ash population size in Canada, causing high mortality in affected areas (see *Threats*). In the United States hundreds of millions to billions of ash trees have succumbed to Emerald Ash Borer and the loss of billions more is anticipated (Poland and McCullough 2006; Wagner and Todd 2015). Ash mortality exceeding 99% of trees above 2.5 cm diameter was observed in highly infested areas in Michigan and Ohio from 2004-2010 (Klooster *et al*. 2014). Later studies in Michigan, some in connection with biological control initiatives, observed persistence of small trees and saplings as well as seed production (e.g., Duan *et al*. 2015, 2017; Kashian 2016). This is discussed in more detail under *Threats and Limiting Factors*. The beetle has spread rapidly since its establishment in Canada in the Windsor, Ontario area. It occurs throughout southwestern Ontario from the Toronto area south and west, is extensively established in the Ottawa and Montréal regions, and is widely known from other parts of Ontario (Figures 4 and 5). In Canada, Emerald Ash Borer has been detected as far as Winnipeg, Manitoba to the northwest and Edmundston, New Brunswick to the east (Figure 5; CFIA 2017, 2018) with a new occurrence detected in Bedford, NS (CFIA 2018). Canadian population decline caused by Emerald Ash Borer cannot be quantified based on available data (Rowlinson pers. comm. 2017; Wilson pers. comm. 2017) but is known to be locally severe (millions of ash trees of all species, with a relatively small proportion being Black Ash, see *Threats*) and is expected to increase in scope.

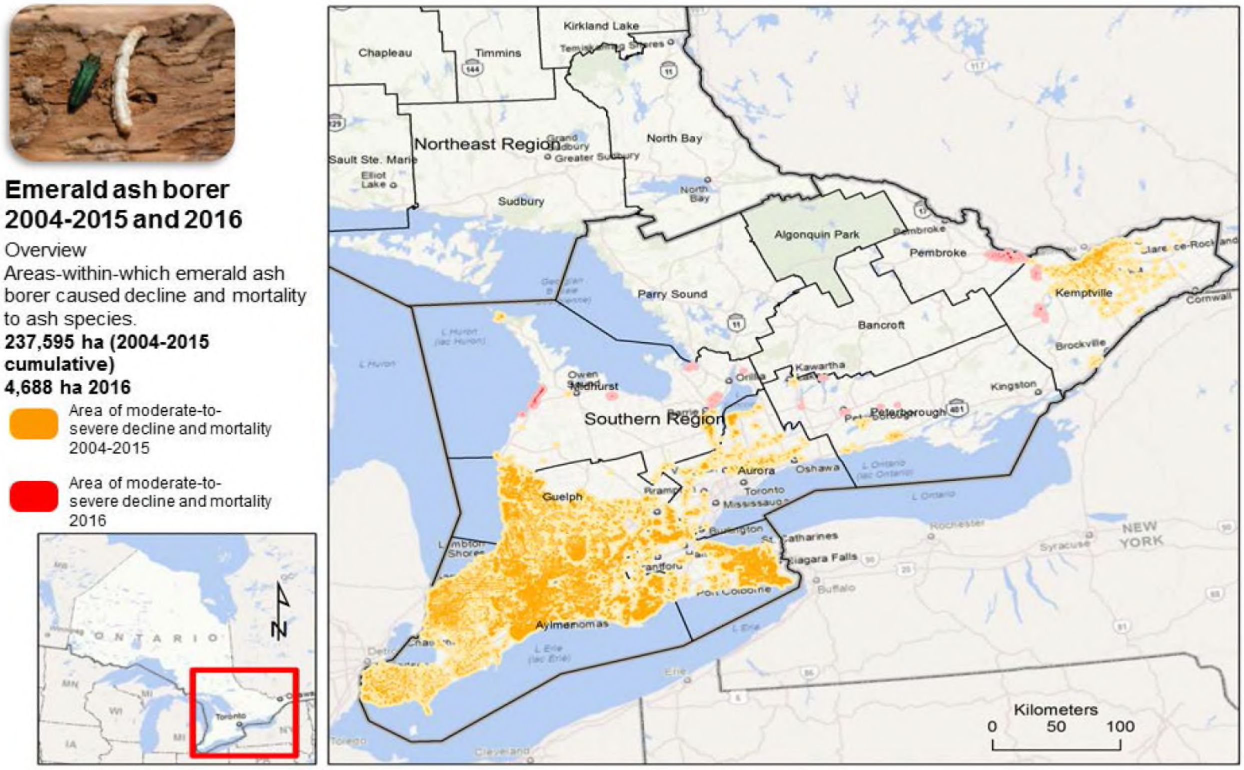

Figure 4. Emerald Ash Borer-caused ash decline and mortality in southern Ontario based on Ontario Ministry of Natural Resources and Forestry aerial surveys (Rowlinson 2017).

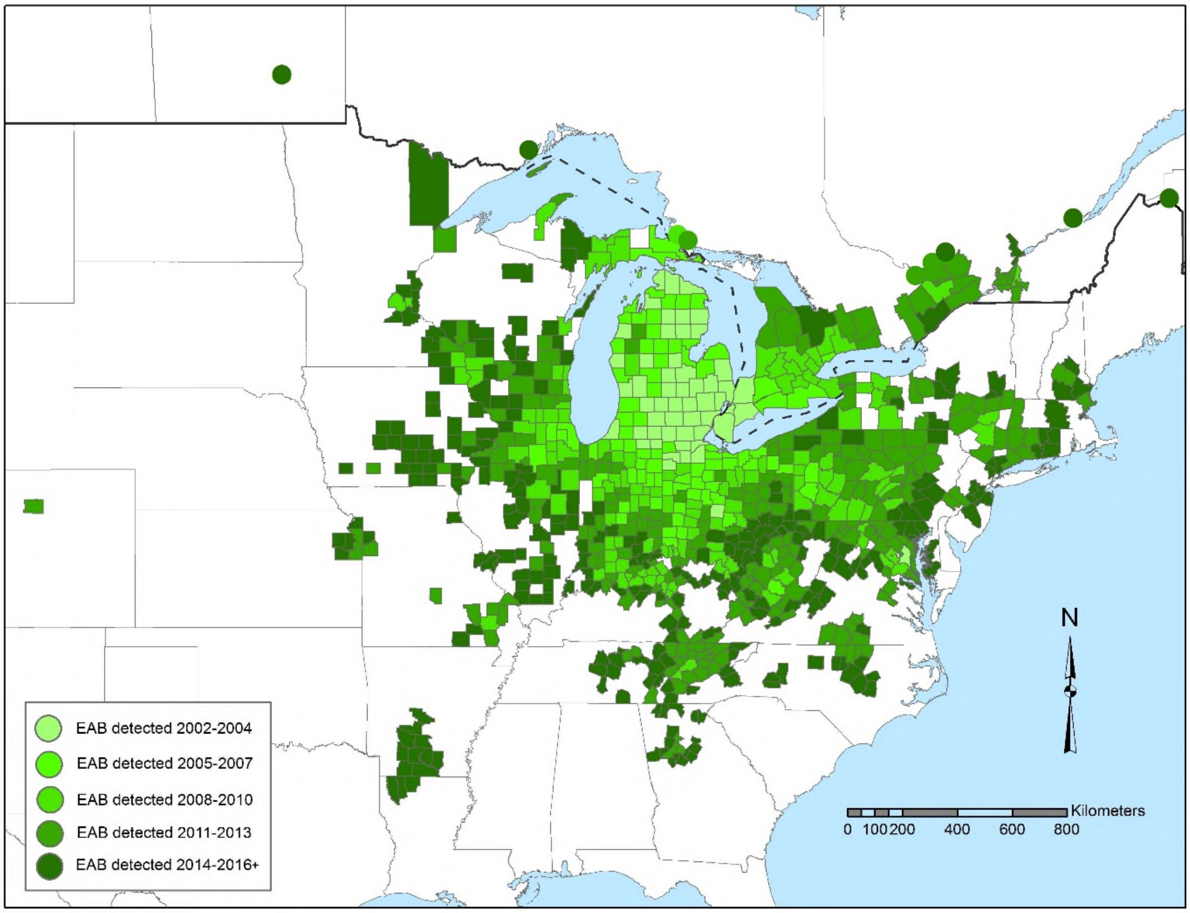

Figure 5. Documented occurrence of Emerald Ash Borer in North America by county or equivalent jurisdiction, except for Manitoba, northern Ontario, New Brunswick and some Quebec occurrences where locations are given as precise dots within large jurisdictions (APHIS 2016; CFIA 2017, 2018).

Mortality caused by Emerald Ash Borer adds to substantial population decline due to habitat conversion in the past three generations (180 years, since 1837). As detailed in *Habitat Trends*, Black Ash habitat in Canada has probably declined by more than 6.4% since 1837, and there is no suggestion that population decline associated with this loss has been compensated by increases in density within remaining habitat. Resulting population declines are likely greater than the proportion of habitat lost because of the higher proportion of habitat loss in the Great Lakes Plains, where the calcareous soils likely supported a higher density of Black Ash. The more acidic and/or climatically marginal regions of the Canadian Shield to the north generally support lower densities of trees. Declines in habitat, which are presumably causing declines in population, continue at a slow rate nationally, estimated at slightly more than 0.021% annually (see *Habitat Trends*).

Over the last two centuries, Black Ash has reportedly become scarcer in calcareous mixed-wood swamps of the Maritime provinces, declining in frequency of occurrence from 6.5% in the early 1800s to less than 1% in 1993 (Loo and Ives 2003). In Nova Scotia, where the species is uncommon and listed as Threatened, provincial forest inventory data suggest a marked decline since the 1950s, perhaps on the order of 45% or more. Evidence of this decline and possible causes are discussed in *Threats*. Mi'kmaq basket makers agree that Black Ash is rare in Nova Scotia but could not recollect any discussions with elders suggesting that the species has declined over time (Meuse and Labrador pers. comm. 2007). Although some Nova Scotia Black Ash has been used in basketry, Nova Scotia Mi'kmaq are known to have brought materials in from Quebec, New Brunswick and Maine over the last 50 years (MacPhail pers. comm. 2007).

In Manitoba, there was some evidence of long-term local population increase up to the 1970s with colonization of moist grasslands near Portage la Prairie, and with ecological replacement of American Elm lost to Dutch Elm Disease along smaller stream floodplains (Ronald 1972; Zoladeski *et al*. 1998), which could also have occurred elsewhere in Canada.

Exceptional densities of introduced White-tailed Deer on Anticosti Island, Quebec and introduced Moose in Newfoundland have likely caused localized declines (see *Threats*), as both species have caused substantial changes in vegetation and are known to commonly browse Black Ash (Elias 1987; Erdmann *et al*. 1987; Wright and Rauscher 1990). The small areas involved and uncommon status of Black Ash in Newfoundland and Anticosti Island mean that any declines caused by introduced deer and Moose are unlikely to be significant in relation to the total Canadian population.

Rescue Effect

Rescue from the United States is unlikely to significantly alter impacts from Emerald Ash Borer because United States populations are more widely affected by EAB than are Canadian ones, areas in Canada already affected by EAB are not expected to become suitable for Black Ash immigrants in the near future (see *Threats – Emerald Ash Borer*), and because further expansion of Emerald Ash Borer along the Canada – United States border will likely concurrently affect areas on both sides the border, limiting source populations for immigration into Canada.

There are no specific reports of Black Ash movement from the United States into Canada. Black Ash seeds are, however, well adapted for dispersal by water and wind, with dispersal on a scale of kilometres likely regular (see *Dispersal and Migration*). Black Ash is still common along most of the Canada – United States border within its range, and thus likely frequently disperses across the border. Dispersal by water or by wind across ice is likely especially frequent over the nearly 1400 km of border within Black Ash range where the border is defined by rivers and smaller lakes[3]. Dispersal across the Great Lakes is likely less common because of the distances involved but is plausible (see *Dispersal and Migration*), while dispersal from the United States well into Canada is likely infrequent.

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[3] roughly 680 km of border from Manitoba to Lake Superior, 110 km along the St. Marys River and Munuscong Lake between Lakes Superior and Huron, 100 km along the St. Clair River between Lakes Huron and Erie (though EAB has likely eliminated most Black Ash here), 50 km along the Niagara River between Lakes Erie and Ontario, 180 km along the St. Lawrence River from Kingston to Cornwall, 37 km along Halls Stream between Quebec and New Hampshire, 120 km along the St. John River in northwest New Brunswick and 200 km along the St. Croix River system in southwest New Brunswick

THREATS AND LIMITING FACTORS

Threats

Black Ash is of national conservation concern only because of the severe threat posed by the introduced Emerald Ash Borer. Other potential rangewide threats of lesser immediacy or magnitude are: 1) the unknown factor (most likely an introduced disease or insect, potentially the Wooly Alder Psyllid - *Psyllopsis discrepans*) that is believed to have caused major declines in Nova Scotia since 1958; 2) the Asian fungal ash disease Chalara dieback (*Hymenoscyphus fraxineus*), which is causing extreme loss of the closely related European Ash in Europe and is virulent in Black Ash but is not yet known in North America; and 3) climate change, which is predicted to significantly reduce the region suitable for Black Ash within one to two generations. Provincial or local scale threats are: 1) logging and wood harvesting, 2) wood and pulp plantations, 3) land conversion for agriculture, renewable energy, industrial, or residential purposes; 4) dieback of unknown causes; 5) severe browsing by dense populations of introduced deer and Moose; and 6) targeted harvesting for firewood and traditional uses.

Threats to Black Ash assessed in this report are organized and evaluated based on the International Union for the Conservation of Nature - Conservation Measures Partnership (IUCN-CMP) unified threats classification system (IUCN 2017). Threats are defined as the proximate activities or processes that directly and negatively affect the Black Ash population and are outlined below in general order of highest to lowest impact. Results on the impact, scope, severity, and timing of threats are presented in tabular form in Appendix 1. The overall calculated and assigned threat impact is ‘medium’ for Black Ash.

<u>Emerald Ash Borer (IUCN Threat 8.1 Invasive Non-native Species)</u>

Emerald Ash Borer (*Agrilus planipennis* Fairmaire; syn: *A. marcopoli* Obenberger, *A. marcopoli ulmi* Kurosawa, *A. ferestrius* Obenberger), henceforth referred to as EAB, is an Asian wood-boring beetle in the family Buprestidae. It was inadvertently introduced to the Detroit, Michigan – Windsor, Ontario area in the 1990s, where it was first recognized in both Canada and the U.S.A. in 2002 (Haack *et al*. 2002; Cappaert *et al*. 2005; Herms and McCullough 2014). EAB is an ash-dependent species that can complete its life cycle in all native Canadian ash species, but Black Ash appears to be the most susceptible of all North American hosts (Smith *et al*. 2005; Rebek *et al*. 2008). EAB is capable of killing trees before they become reproductive (Kurmis and Kim 1989; Klooster *et al*. 2014), at diameters of 2.5 cm and above (McCullough *et al*. 2008; Klooster *et al*. 2014). Tree mortality is via disruption of conductive tissue caused by larval feeding in the sapwood and inner bark (BenDor 2006; Poland and McCullough 2006). Even in large, healthy trees mortality can occur within three years, with modelling based on field observation suggesting 50% stand mortality after four years (Knight *et al*. 2007) and observation indicating 99% ash mortality (all species) by six years in Michigan and Ohio (Klooster *et al*. 2014, 2018). Potential for natural recovery after these levels of mortality was initially believed to be very low (but note evidence of potential for recovery below). The soil seed bank is rapidly depleted if mature trees are completely lost. Viable seed density in an infested stand decreased from 500,000 per ha in 2005 when 42% of ash trees had died, to 130,000 per ha in 2006 when 77% of trees had died, to 0 in 2007 (Klooster *et al*. 2013). EAB can persist at low levels for many years, feeding on saplings as they become large enough to be attacked (Knight *et al*. 2014).

EAB are strong fliers with high dispersal potential. Laboratory studies of tethered EAB suggest that mated female beetles can travel 20 km over four days (median distance >3 km, with 20% flying >10 km and 1% flying >20 km; Taylor *et al*. 2005) and 20 km / year has been used as an estimate of rate of spread (Prasad *et al*. 2010). Tornados and other strong storms could increase potential dispersal distances considerably (Compton 2002; McKinney *et al*. 2013), as can human-assisted dispersal via transport of firewood (Muirhead *et al*. 2006; Siegert *et al*. 2014), nursery stock, untreated lumber and wood products (McCullough and Katovich 2004; Iverson *et al*. 2016). Spread at 30-40 km / year was documented from 2009 to 2013 around Moscow, Russia, which was speculated to be partly caused by vehicle-assisted movement of beetles on highway corridors (Straw *et al*. 2013). Peripheral EAB occurrences hundreds of kilometres from the core North American range demonstrate its long distance dispersal potential (APHIS 2016; CFIA 2017; Figure 5). The known Canadian range of EAB presently includes outliers in Winnipeg, Manitoba and the Thunder Bay and Sault Ste. Marie areas of northern Ontario, extensive establishment through southern Ontario to Montréal, Quebec, and outliers in the Berthierville, Quebec, Quebec City, Edmundston, New Brunswick, and Bedford, Nova Scotia areas (CFIA 2017; 2018). In the US, the species is now known from at least 770 counties in 26 states, from Minnesota, Iowa and Colorado in the west to New Hampshire in the east and as far south as Louisiana and Georgia (Figure 5; APHIS 2016). No Canadian Black Ash occurrences are more than 1,000 km from currently affected areas. Almost all the Ontario and Quebec occurrences that represent approximately 95% of the Canadian population are less than 500 km from currently affected areas. These distances are less than the 1,110 km to 1,300 km distance EAB has already covered from Detroit-Windsor to the peripheries of its current distribution at Winnipeg and Edmundston, New Brunswick (Figure 5). If there were no factors limiting its northward spread, all portions of Black Ash range in Canada would likely be experiencing EAB invasion within about one generation (60 years).

EAB has caused dramatic ash mortality in North America, particularly where it first became established in the Great Lakes region (Cappaert *et al*. 2005; Siegert *et al*. 2007; Burr and McCullough 2014; Klooster *et al*. 2014, 2018; Knight *et al*. 2014). Over 100 million ash trees (all species) were estimated to have been killed by 2012 (McCullough unpubl., as cited in Donovan *et al*. [2013]) and perhaps as many as 2 billion by 2015 (Wagner and Todd 2015). The mortality is escalating and loss of a high proportion of the 8.7 billion ash trees in the United States (Flowers *et al*. 2013) could ultimately occur (Wagner and Todd 2015).

In Ontario, the spread of EAB mortality is extensively monitored through annual aerial surveys by the Ontario Ministry of Natural Resources and Forestry (Rowlinson 2017). Total cumulative area experiencing moderate to severe mortality was 235,595 ha as of 2016, including 4,688 ha added in 2016 (Rowlinson 2017; Figure 4). Almost all ash-containing forest south and west of Toronto is within this category, with an additional concentration of affected area around Ottawa that was first detected in 2008. Many other smaller affected areas occur elsewhere in southern Ontario (Figure 4). Quantification of the total number of ash trees (all species) thus far affected in Canada has not been attempted but it is clearly in the millions[4]. By 2010 several hundred thousand ash trees had been killed in Essex County, Ontario alone (OMNR 2010), which at less than 2% of the area of southern Ontario and only ~8% forest cover (the lowest of any county in Ontario, City of Windsor 2017), represented only a tiny fraction of ash trees in the currently affected zone. In southwestern-most Ontario, especially from Windsor to London, ash mortality is very high (Rowlinson pers. comm. 2017). EAB has also become well established around Montréal (first detected in 2011) and mortality in that region is becoming locally severe (Lavallée pers. comm. 2018). With EAB established in almost all counties in southern Ontario and adjacent Quebec (Figures 4 and 5) and rapidly expanding from current infestations, most of the southern Ontario and southern Quebec range of Black Ash could experience extreme mortality similar to that in Michigan and Ohio within one to two decades.

While the potential impact of Emerald Ash Borer on Black Ash in Canada is very significant, there are a number of reasons that losses across the Canadian range may ultimately be less than the 99% documented locally in Michigan and Ohio. Ash tree mortality is known to be moderated on a local scale by genotype, ash tree age, vigour, and stand density, pest population outbreak stages, climatic factors and native EAB parasitoids and predators (see extensive references in Duan *et al*. 2017). The majority of Black Ash's Canadian range is within regions of relatively contiguous forest, differing from the moderately to highly fragmented nature of much of heavily EAB-impacted areas of the United States and southernmost Ontario and Quebec. The extent that might affect rate of EAB spread, especially when combined with potentially more marginal climatic conditions for EAB as it moves northward, is unclear. The most significant research that indicates some potential for ash persistence is outlined below.

a) Climatic limitation of EAB expansion northward

Most overwintering EAB may not be able to withstand temperatures below -30°C and the lowest reported temperature at which EAB has resisted lethal freezing is -35.3°C (Venette and Abrahamson 2010; Crosthwaite *et al*. 2011). Cold temperatures will thus likely limit EAB and allow greater survival of Black Ash in northern parts of its range (Cappaert *et al*. 2005; DeSantis *et al*. 2013; Figure 6) than has occurred in Michigan, Ohio and southern Ontario. However, the insulating capacity of snow cover and bark mean that temperatures experienced by overwintering EAB larvae are frequently 2°C to 5°C warmer than the surrounding air temperature (DeSantis *et al*. 2013). This effect may explain ash mortality caused by EAB establishment at Winnipeg, Manitoba and Thunder Bay and Sault Ste. Marie, Ontario, which are at or well north of the -30°C average annual minimum temperature zone (McKenney *et al*. 2014; Figures 6 and 7).

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[4] The proportion of Black Ash within the ash killed thus far is likely fairly low, as White Ash and Red Ash are considerably more numerous than Black Ash within the regions most affected to this point (Blaney pers. obs. 1989-2016).

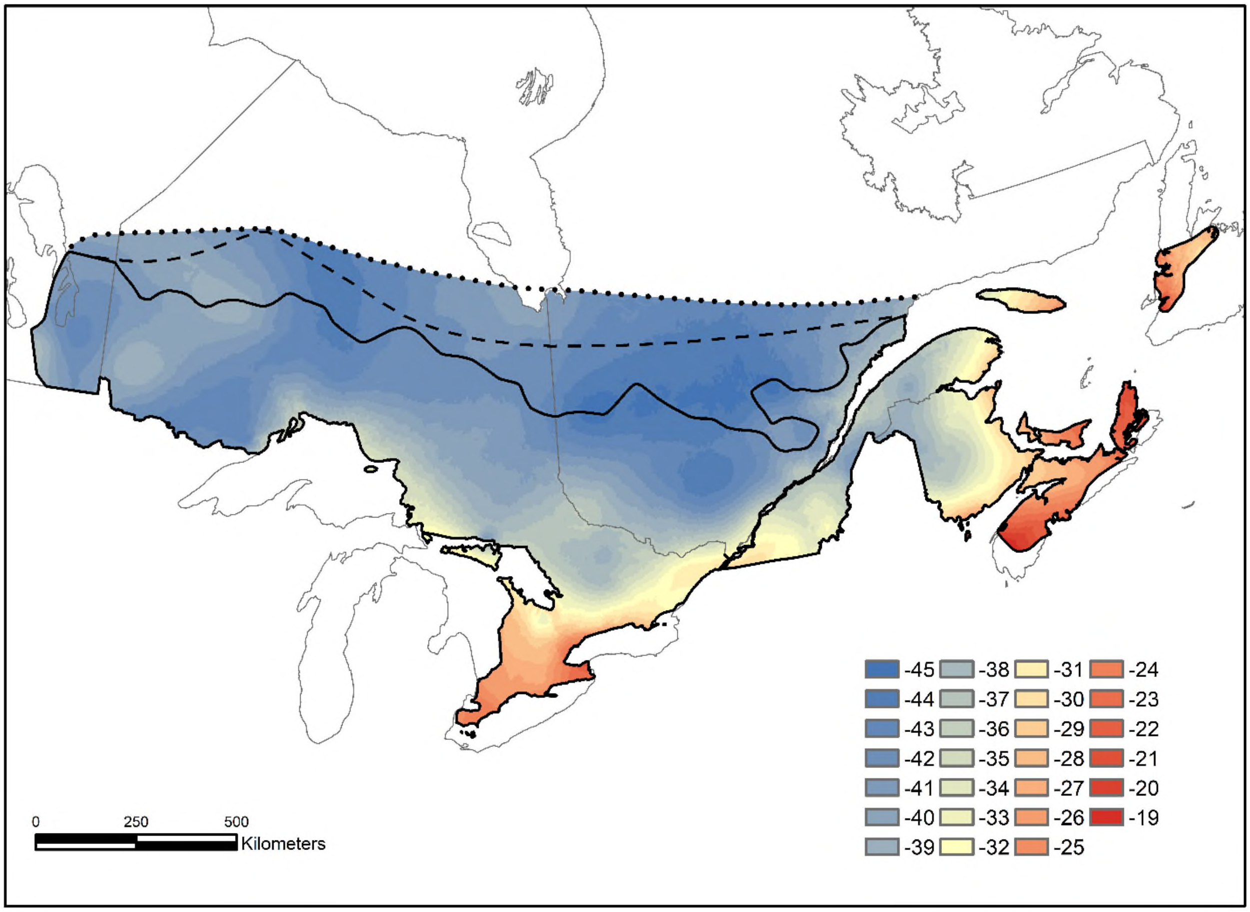

Figure 6. Extreme minimum annual air temperature zones within Black Ash range (climate data from McKenney *et al*. 2014). The southern range limit (solid line) is based on published range maps (Farrar 1995; Watkins 2011), the middle dashed range limit is inferred from occurrence records known north of published range maps and the hatched line indicates a potential maximum northern limit, based primarily on Baldwin (1958), who suggested occurrence north to 51.83ºN near James Bay.

Blaney *et al*. (2018) analyzed the proportion of the Canadian population of Black Ash that might be protected from EAB by cold climate. Using the same GIS interpolation of EAB-experienced minimum temperatures that was utilized in DeSantis *et al*. (2013), they found that the insulating effects of snow and bark are very significant in attempting to assess future impacts of EAB on Black Ash in Canada. If air temperatures of -30°C were sufficient to kill all overwintering EAB, only 1.66% of Canadian Black Ash would be susceptible (Table 1; using temperature averages for the last 10 years). When insulating effects of snow and bark are accounted for, 72.8% of Canadian Black Ash is susceptible to EAB (i.e. is within zones in which EAB-experienced minimum temperatures average warmer than the most widely cited minimum survivable temperature of -30°C; Table 2); even if the minimum EAB-experienced survivable temperature was only -26°C, that would still leave 50.39% of the Canadian population of Black Ash potentially susceptible to EAB (Table 2).

Table 1. Proportional Black Ash susceptibility to EAB by province and nationally, within temperature zones representing theoretical minimum survivable temperatures for EAB (from Blaney *et al*. 2018). For example, the value for Canada under -37C indicates that if -37°C is the minimum survivable temperature for EAB, 27.87% of Canadian Black Ash are susceptible to EAB and 72.13% of Canadian Black Ash are protected from EAB by climate. The climatic layer used for this analysis was the minimum monthly air temperature raster dataset from Dan McKenney (Canadian Forest Service) for 2005-2014.

Minimum annual air temperature zone, and percentage of Black Ash susceptible to EAB if given temperature represents the minimum survivable temperature for EAB

	-45C	**-44C**	**-43C**	**-42C**	**-41C**	**-40C**	**-39C**	**-38C**	**-37C**	**-36C**	**-35C**	**-34C**	**-33C**	**-32C**	**-31C**	**-30C**	**-29C**	**-28C**	**-27C**	**-26C**	**-25C**	**-24C**	**-23C**	**-22C**	**-21C**
Ontario	100	99.97	89.68	76.85	65.59	51.19	41.74	33.23	18.85	14.14	10.91	8.74	6.88	4.43	2.97	2.56	2.25	1.73	1.26	0.72	0.41	0.14	0.03	0.01	0.00
Quebec	99.75	96.90	90.51	82.25	74.46	66.75	56.47	45.28	33.25	26.31	20.79	12.45	7.82	4.26	2.75	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Brunswick	100	100	100	100	100	98.80	91.00	82.53	71.52	62.62	54.32	43.90	32.96	24.25	15.72	6.69	2.05	0.87	0.36	0.04	0.00	0.00	0.00	0.00	0.00
CANADA	99.89	98.62	90.57	80.40	71.24	60.45	50.73	41.04	27.87	21.96	17.47	12.16	8.62	5.37	3.53	1.66	1.25	0.93	0.66	0.37	0.21	0.07	0.02	0.01	0.00

Table 2. Proportional Black Ash susceptibility to EAB by province and nationally, within temperature zones representing theoretical minimum survivable temperatures for EAB (from Blaney *et al*. 2018). The climatic layer used for this analysis was the minimum EAB-experienced temperature raster dataset compiled by DeSantis *et al*. (2013).

Minimum Annual EAB-experienced temperature zone, and percentage of Black Ash susceptible to EAB if given temperature represents the minimum survivable temperature for EAB

	-35C	**-34C**	**-33C**	**-32C**	**-31C**	**-30C**	**-29C**	**-28C**	**-27C**	**-26C**	**-25C**	**-24C**	**-23C**	**-22C**	**-21C**	**-20C**	**-19C**	**-18C**	**-17C**	**-16C**	**-15C**
Ontario	100.0	99.98	99.81	97.40	78.16	53.41	48.36	47.03	40.26	30.39	25.01	19.11	14.40	11.03	8.13	4.59	2.95	2.26	1.84	1.04	0.30
Quebec	100.0	100.0	99.75	95.63	93.45	92.18	90.90	86.02	80.89	69.23	46.63	17.57	1.46	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Brunswick	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.34	88.11	76.78	64.23	45.16	24.71	7.81	3.32	0.00	0.00	0.00	0.00	0.00
CANADA	100.0	99.99	99.79	96.76	85.99	72.82	69.68	66.86	61.12	50.39	37.15	20.74	10.29	6.94	4.55	2.51	1.51	1.15	0.94	0.53	0.15

The Blaney *et al*. (2018) analysis does not allow definite prediction of Black Ash population loss. It does suggest that loss of 50% of the Canadian Black Ash population is possible within one generation, but the potential susceptibility of 72.8% of the Canadian Black Ash population to EAB (Blaney *et al*. 2018) does not necessarily mean that 72.8% of the Canadian population will be lost. Ash mortality south to north will likely be on a gradient from high to low, corresponding to the gradient in EAB mortality with decreasing minimum temperatures (Venette and Abrahamson 2010; Crosthwaite *et al*. 2011; Sobek-Swant *et al*. 2012). The extent of cold-induced EAB mortality that would significantly reduce ash mortality is not yet well understood.

Analysis of future EAB effects is further complicated by the expectation of a warming climate (IPCC 2014; Iverson *et al*. 2016). In general, a warming climate would be expected to move climate zones northward and enhance northward survival of a presumed climate-limited insect such as EAB (Dukes *et al*. 2009). IPCC (2014) climate predictions for 2100, including error bars, range between about 1°C and 4°C above current temperatures. If that level of warming equated to a corresponding increase in minimum annual temperatures, there would be very little Black Ash with any climatic protection from EAB. For example, if temperature zones shifted northward by 1°C to 4°C, that would leave 85.99% to 99.99% of Canadian Black Ash susceptible to EAB (Table 2; susceptibility values of -31°C and -34°C). Many possible interacting effects could, however, alter outcomes associated with a warmer climate. For example, annual minimum temperatures could remain stable within a warming climate; warmer fall temperatures and increased freeze-thaw cycles in a warming climate could reduce EAB tolerance to rare cold extremes; or snow levels could increase in some regions, increasing insulating effects.

EAB is now established at Winnipeg, Manitoba (CFIA 2018) within the zone for which DeSantis *et al*. (2013) indicated potentially significant climatic limitations on EAB impacts, associated with typical minimum annual air temperatures in the range of -35°C. The long-term persistence of EAB and the effects of EAB on ash in Winnipeg are still unclear, but the previous three winters (2015-2017) in Winnipeg have not had any air temperatures below -31°C (based on The Forks weather station, roughly 1 km from the Winnipeg site of EAB infestation; ECCC 2018), and thus could resemble a future, warmer climate.

b) Natural recovery following severe EAB effects

In a five-year study (2010-2014) of 17 small, nearly pure stands of Red Ash near Detroit, Michigan, Kashian (2016) observed regeneration, including recruitment into the canopy, despite a well-established population of EAB. Reproduction was via: 1) post-infestation survival of canopy trees; 2) basal sprouts from top-killed trees; 3) seedlings and saplings established prior to EAB impacts; and 4) seeds produced by surviving canopy trees and basal sprouts. This work demonstrated the need for a distinction between stem mortality and whole individual mortality, which is perhaps not well made in some previous studies. Among individual stems killed by EAB, Kashian (2016) found that 62% sprouted vegetatively from the base. The basal sprouts grew much faster than seedlings and in a mast year 27% of large sprouts produced seed when most or all were less than 10 years old. Kashian (2016) also found a lower total rate of stem mortality (58%) in his stands than had been reported elsewhere in Michigan and Ohio. Although not discussed in the paper, his field sites were in or adjacent to counties that received the first introductions of the EAB parasitoid *Tetrastichus planipennisi* for biological control in 2007 (Duan *et al*. 2013). This species is now well-established in the area and could be contributing to greater ash success there. Aubin *et al.* (2015) examined ash regeneration in the Essex county area (southwestern Ontario) following EAB infestation and found abundant ash regeneration in the area. They indicated that there was a low chance that the regenerated ash would reach maturity as there is a presence of EAB within the area and documented a 19% infestation rate in the regenerating ash stems. Kashian (2016) suggests that pure ash stands may more effectively resist EAB than ash in the mixed hardwood stands that predominated in earlier studies (Kashian and Witter 2011; Burr and McCullough 2014; Klooster *et al*. 2014). He concludes that the seed-producing ability of small trees and basal sprouts and persistence of some larger individuals will allow Red Ash to remain an important component of forests at his study sites, albeit at a smaller stature and lower density than under pre-EAB conditions. The extent to which his results apply to Black Ash is unclear, but they do give some indication that one can not necessarily assume complete loss from EAB.

c) Biological control of EAB through introduced Asian parasitoid wasps

Research into biological control of EAB began in 2003 immediately after it was identified as a serious invader in North America and is summarized in Bauer (2015). Introductions of three parasitoid wasps from China began in the United States in 2007: the egg parasitoid *Oobius agrili* (Hymenoptera: Encyrtidae) and the larval parasitoids *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) and *Spathius agrili* (Hymenoptera: Braconidae). Releases have continued and as of 2013 had been completed in several hundred sites in 105 counties of Minnesota, Wisconsin, Michigan, Illinois, Missouri, Indiana, Ohio, Kentucky, Tennessee, West Virginia, Virginia, Maryland, Pennsylvania and New York (MapBioControl 2013). Releases of *Oobius agrili* and *Tetrastichus planipennisi* in Canada began in 2015 and 2016 in southwestern Ontario (seven sites in Toronto area and westward), and around Ottawa (two sites) and Montréal (three sites) (Ryall 2017). Establishment of *Spathius agrili* has not been recorded in northern areas, thus for American sites above 40 degrees latitude, it was replaced by the larval parasitoid *Spathius galinae* of the Russian Far East in 2015. This species was approved for release in Canada in 2017 (Duan *et al. 2018*).

In the most intensively studied biological control release site in southern Michigan, *Tetrastichus planipennisi* broods are present in up to 92% of trees with signs of EAB (Duan *et al*. 2013), with densities now uniform in release and non-release sites (Duan *et al*. 2017). Life table analysis shows that observed rates of *T. planipennisi* parasitism on EAB larvae reduce the EAB population growth rate in small to medium-sized trees (Duan *et al*. 2015) and in saplings (Duan *et al*. 2017), for the latter by 50%. Ultimate effects of reduced EAB population growth rate on ash survival in larger size classes is still unclear (Duan *et al*. 2017). Kashian *et al.* (2018) summarized the strong positive trends in EAB biocontrol on Green Ash and White Ash yet indicated that more time is needed to determine the effect of EAB biocontrol on ash health and regeneration. Documented rates of spread of *T. planipennisi* range from a minimum of 1 km/year to 5+km/year (Duan *et al*. 2014) but are still incompletely understood. Biological control researchers are "guardedly optimistic" that EAB densities can be kept at levels that allow significant ash persistence (Bauer *et al*. 2015). This might be accomplished through the additive effects of natural expansion of established populations of EAB parasitoids, continued releases of biological control species (with the addition of *Spathius galinae*, which has a longer ovipositor that may allow greater control of EAB on mature trees with thick bark) and anticipated increased effects from native natural enemies (woodpecker species – Picidae, and several parasitoid wasps, especially *Atanycolus* spp., Braconidae) (Bauer *et al*. 2015; Duan *et al*. 2017).

In Canada, the biological control program for EAB is still in its early stages, led by the Canadian Forest Service's Great Lakes Forestry Research Centre, but it is developing its own rearing capacity and is continuing with a program of expanding research releases (Ryall 2017).

Other EAB-inspired ash conservation research programs include: 1) breeding of putatively resistant remnant native trees (Koch *et al*. 2012; Herms *et al*. 2014a); 2) backcross breeding programs aiming to introduce resistance genes from Asian or European species into native ash (Koch *et al*. 2012; Herms *et al*. 2014a; Villari *et al*. 2014); and insecticide control of EAB (Herms *et al*. 2014b). Potential effects of these efforts are longer term or more local and are less relevant to status assessment.

Undetermined Disease or Insect Species in Atlantic Canada (IUCN Threat 8.3 Problematic Species/Diseases of Unknown Origin)

Conclusive evidence of the cause of Black Ash decline and poor health in Nova Scotia and adjacent areas of New Brunswick and Prince Edward Island is lacking. These may, however, be due to the leaf damaging effects of Cottony Ash Psyllid (*Psyllopsis discrepans*, family Psyllidae), an aphid-like homopteran insect native to Europe that uses European Ash as a major host species (Ossiannilsson 1992), and/or due to an introduced disease it transmits.

There are two lines of evidence suggesting significant declines in Nova Scotia since the 1950s: 1) reduced volumes and distribution, and lack of recruitment noted in provincial forestry data; and 2) the almost complete absence today of healthy, large, reproductive trees in Nova Scotia, Prince Edward Island and southeastern New Brunswick (AC CDC 2016), with most having crown dieback and some or many curled leaves. Similar patterns of curled leaves and crown dieback have been observed in Newfoundland (Humber pers. comm. 2017). As outlined below, the cause or causes of declines are unknown, but a disease or insect (most likely an introduced species) seems the most plausible explanation. Whatever is causing low vigour and decline in the region could represent a significant threat for the remainder of the range, were it to spread.

Provincial forest inventory data from 1958 (5,350 plots throughout the province; Hawboldt and Bulmer 1958) estimated gross volume (ground to tip volume of trees >10 cm diameter at breast height) of Black Ash at 151,434 m^3 and gross merchantable sawlog volume (volume of trees >25 cm diameter at breast height, from ground to ~10 cm top diameter) at 14,143 m^3. Original data have been lost and methods involved in volume calculation are not given, but this likely involved about 55 trees[5]. In the 1958 inventory data, Black Ash was found in all Nova Scotia counties (including Shelburne and Yarmouth Counties where extensive recent fieldwork has found no records, AC CDC 2017). This finding from a randomized survey covering only 0.019% of the landscape[5] strongly suggests that Black Ash was much more abundant in 1958 than it is today. The fact that trees >25 cm diameter at breast height were recorded in 1958 is also telling, given that only four recent Nova Scotian occurrences out of 197 in which size was recorded have trees exceeding ≥20 cm diameter at breast height (AC CDC 2017) and no trees of that size have been recorded in permanent sample plots since 1981 (NS DNR 2017; see below).

Since 1965, Nova Scotia's permanent sample plots have been revisited on a five year rotation, allowing tracking of individual trees and some indication of population trends. The

[5] 1958 plots were 0.2 ha, meaning the 5,350 plots would have covered 0.019% of Nova Scotia and plot data would be extrapolated to the whole province by a factor of 5,166. The 151,434 m^3 estimated total volume (roughly 285,000 trees, vastly greater than would be present today) would thus represent 29.31 m^3 of observed volume, or about 55 mature trees (0.13 m average diameter x 10 m log length).

rarity of Black Ash means that sample sizes are small, but these data strongly point to decline. Since 1965, 23 trees above 10 cm diameter at breast height have been recorded in eight plots, and a minimum of 520 saplings (under 10 cm diameter at breast height) have been recorded in 39 plots. There has been no recruitment into the 10+ cm diameter class recorded since 1980 and all 23 trees ever recorded are now dead (10 recorded as cut, 12 as standing dead, one with no record after 1965). None of the six plots recorded as having 10 or more saplings in the past had any saplings in the most recent survey period, and although saplings continue to be recorded in new plots (21 plots had their first record of sapling Black Ash after 1990), none of these plots have retained saplings to a second five year inventory cycle.

Presuming a substantial decline has occurred since 1958, a disease or insect attack is the most plausible cause. Although about 80.2% of Nova Scotia's forest is less than 80 years old (586 of 2959 permanent sample plots in 2011-2015; NS DNR 2017), most of which would have regenerated from land cut over since 1958, there is no indication from elsewhere in the range of Black Ash that forestry alone would be likely to cause major population declines and range contraction (see *Threats – Forestry*). Neither would forestry impacts account for observed lack of reproductive trees and poor health of individuals. Black Ash in Nova Scotia at present is generally small, non-reproductive and frequently visibly unhealthy (Blaney and Mazerolle pers. obs. 2000-2016; AC CDC 2017). Out of 197 recent Nova Scotian occurrence records in which size was noted, involving approximately 529 individuals, only 11 trees at ten sites were noted as "large", "mature", or over 20 cm diameter at breast height (AC CDC 2017), and only one was noted as reproductive. Most Nova Scotian Black Ash examined in a province-wide study in 2004 were reported as being in decline with no identified cause; 98% of closely monitored trees exhibited some dieback and average dieback per tree was ~17% across nine sites over two years (Hill-Forde 2004).

No specific cause of Black Ash population decline and poor health in Nova Scotia, Prince Edward Island and adjacent southeastern New Brunswick has yet been identified. A non-native disease or insect is a plausible cause given that no native pathogens are known to substantially influence populations (see *Limiting Factors*). Halifax is a major seaport and an important pathway of introduction for invasive organisms into North America, having been the first point of North American introduction for Beech Bark Disease (Gavin and Peart 1993) and the Brown Spruce Longhorn Beetle (*Tetropium fuscum*; Smith and Hurley 2000). Nova Scotia also has well-established planted and wild populations of European Ash (*F. excelsior*) which could have served as a vector for disease or insect pests. A prominent symptom of unhealthy Black Ash in the region is heavily curled leaves (Figure 8; Blaney and Mazerolle pers. obs. 1999-2017). These could have a variety of causes. One noted in the literature is Cottony Ash Psyllid (*Psyllopsis discrepans*) (Ossiannilsson 1992). This aphid-like true bug (Psyllidae, Homoptera) was first found in Canada in Nova Scotia in 1921, which was the second North American record after one in Rhode Island around 1907 (Hodkinson 1988; Culliney and Koop 2005). Cottony Ash Psyllid has more recently been documented in Ontario, Saskatchewan, Alberta, Michigan, Minnesota and North Dakota, with severe damage noted on planted ash trees in western Canada and North Dakota (Culliney and Koop 2005; Fauske *et al*. 2005; Maw *et al*. 2010; City of Saskatoon 2013; Percy 2014; City of Calgary 2017; City of Edmonton 2017; Mason undated). In North

America, it affects both Black Ash and Manchurian Ash (*F. mandshurica*), as well as hybrid cultivars of the two species (Mason undated). Nymphs feeding on foliage typically cause a curling and yellowing of leaflets and gradual dieback. A homopteran insect that is likely Cottony Ash Psyllid (definite identification of the immature specimen not possible) was collected from curled Black Ash leaves on the Taxis River in central New Brunswick in 2017 (Blaney and Mazerolle pers. obs. 1999-2017). This lends further evidence to the theory that Cottony Ash Psyllid, and/or disease that it transmits, is significantly affecting Black Ash health in the Maritimes and possibly elsewhere.

Chalara Dieback (IUCN Threat 8.1 Invasive non-native disease)

The fungal disease Chalara Dieback is a serious potential future threat not yet known in North America. It is caused by the anamorph of the non-native ascomycete *Hymenoscyphus pseudoalbidus* (anamorph name *Chalara fraxinea*). Black Ash is reported to be highly susceptible to this virulent ash disease (Pautasso *et al*. 2013), meaning that if it were introduced, effects could be severe.

The Asian Manchurian Ash is colonized by the Chalara Dieback fungus but shows a greater resistance to it than do European species, suggesting that the two species may have co-evolved (Queloz *et al*. 2011; Pautasso *et al*. 2013). Molecular studies have provided convincing evidence that the fungus originated in eastern Asia (Zhao *et al*. 2012). Drenkhan *et al*. (2014) speculate that it reached Europe via introduction of Manchurian Ash stock from Asia. *Chalara fraxinea* was only described as a new species in 2006 after severe European Ash decline had been observed in several Northern European countries (Kowalski 2006). The disease now called Chalara Dieback was first noted in Poland in the 1990s and has rapidly spread to most eastern, central and northern European countries, decimating populations of European Ash (*Fraxinus excelsior*; Pautasso *et al*. 2013). The pathogen now threatens the survival of European Ash throughout most of its native range and constitutes one of the foremost threats to European forestry and biodiversity (Kowalski and Holdenrieder 2009; Pautasso *et al*. 2013). All developmental stages from sapling to tree are affected, showing blackish discolouration and wilting of foliage, dieback of shoots and twigs, formation of epicormic shoots, longitudinal bark cankers and xylem necroses, eventually leading to death (Halmschlager and Kirisits 2008; Kowalski and Holdenrieder 2009).

Climate Change (IUCN Threat 11 Climate change & severe weather)

Changes in climate at the magnitude and speed predicted by the Intergovernmental Panel on Climate Change (IPCC 2014) will likely bring about considerable changes in forest composition and ecosystem processes in North America (Iverson *et al*. 2008). Although climate change does not represent an immediate threat to Black Ash, it is ongoing and could have a profound impact on the status and distribution of the species within one to three generations (180 years) into the future. The species' present natural distribution limits are believed to be mainly determined by climate, with a northern extent likely limited by lack of degree days (with late flowering resulting in incomplete fruit maturation) and a southern limit likely determined by a lack of chilling that prevents dormancy break (Morin *et al*. 2007).

Climate warming is therefore expected to gradually push Black Ash range northward to the extent allowed by its dispersal and regeneration potential. The extent of this anticipated range shift and population loss could be mitigated by evolutionary response (Alberto *et al*. 2013). In a detailed modelling study on the redistribution of North American tree species under five climate change scenarios, all five scenarios resulted in a >50% range contraction for Black Ash within the U.S. by 2100 and a slow northward latitudinal shift (Iverson and Prasad 2002). Climate change-induced range shifts were also studied by Morin *et al*. (2008), who employed models incorporating phenology, frost injury, survival, reproductive success and dispersal potential, and predicted much more severe effects for Black Ash than Iverson and Prasad (2002). Based on two International Panel on Climate Change (IPCC) climate change scenarios for 2100, their modelling predicts that over the course of this century, Black Ash will see extirpation over 97.8% of its global range (including the US, Atlantic Canada, southern Ontario and southern Quebec), a decreased probability of occurrence within over half of its remaining range, and a very modest range expansion to the north and northeast (although the current northern range limit used in their model was underestimated). Morin *et al*. (2008) found that the projected extinction rate (defined as percent reduction of range over time) was highest for Black Ash, by a significant margin, among the 16 North American tree species assessed (Morin *et al*. 2008). None of the modelling studies above take into account the additional effect of threats such as pests, disease or anthropogenic habitat alteration.

Climate change can influence forest disturbance by insects and pathogens through: 1) direct effects on the development, survival and dispersal of pathogens and herbivores, 2) changes in tree physiology that can influence resistance to pathogens and herbivores and 3) indirect effects from changes in the abundance of insect vectors of tree pathogens (Ayres and Lombardero 2000; Sturrock *et al*. 2011; Weed *et al*. 2013). A compounding effect of climate change on EAB invasion could be particularly significant in Canada, especially in the northern portion of Black Ash's range, where low winter temperatures may currently limit the beetle's northward spread (see *Threats - Emerald Ash Borer*). The interaction of these two threats could magnify the severity of each issue, facilitating invasion and reducing the resilience of Black Ash to a changing climate (Tluczek 2011; Iverson *et al*. 2016).

<u>Logging and Wood Harvesting (IUCN Threat 5.3)</u>

The threat described here applies only to harvesting on sites that are subsequently left to regenerate naturally and does not include forest conversion to other uses. Discussion of suppression of broad-leaved species to enhance conifer regeneration, which often follows commercial forest harvesting, is given under *Wood and Pulp Plantations* below.

Although Black Ash does not represent a major source of timber or pulpwood in Canada, a considerable number of trees are cut annually through commercial forest harvesting. Most of the Canadian range of Black Ash is on publicly owned land within which commercial forestry is a major factor in landscape change (Global Forest Watch 2010, 2013; MFFPQ 2015; OMNRF 2016b). In Ontario, Quebec and New Brunswick, which contain the species' core Canadian range, collective annual forest area harvested has averaged 334,000 ha in recent years (Natural Resources Canada 2013, 2014, 2015), which represents roughly 0.36% of Black Ash's extent of occurrence, equating to 21.6% over 60 years (one generation); calculations beyond 60 years are complicated by second harvests of the same areas. Figures 9 and 10 (from Global Forest Watch 2010, 2013) indicate the extensive cumulative impacts of forest harvesting within the range of Black Ash, showing that even if population effects were small at a local scale they may be impacting a substantial portion of the Canadian population over time.

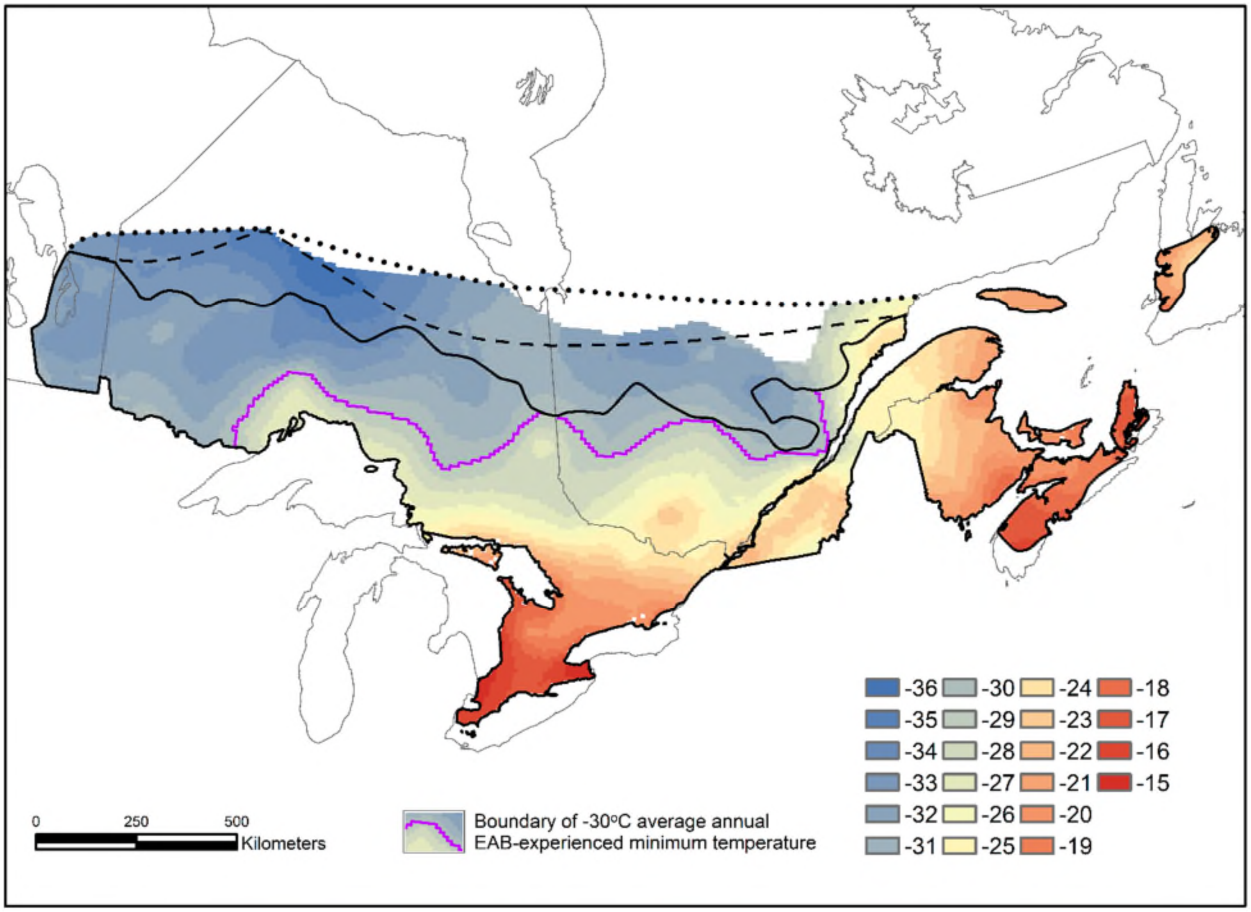

Figure 7. Extreme minimum annual Emerald Ash Borer-experienced air temperature zones within Black Ash range (climate data from DeSantis *et al*. 2013; based on historic to 2012 climate station records). The purple line indicates the northern limit of EAB persistence (minimum annual EAB-experienced temperature above -30º). The southern range limit (solid line) is based on published range maps (Farrar 1995; Watkins 2011), the middle dashed range limit is inferred from occurrence records known north of published range maps and the hatched line indicates a potential maximum northern limit, based primarily on Baldwin (1958), who suggested occurrence north to 51.83ºN near James Bay.

Figure 8. Black Ash with curled leaves caused by unknown agent (possibly Cottony Ash Psyllid – *Psyllopsis discrepans*) at Lazares Brook, Gloucester County, New Brunswick (above) and Missiguash, Cumberland County, Nova Scotia (below).

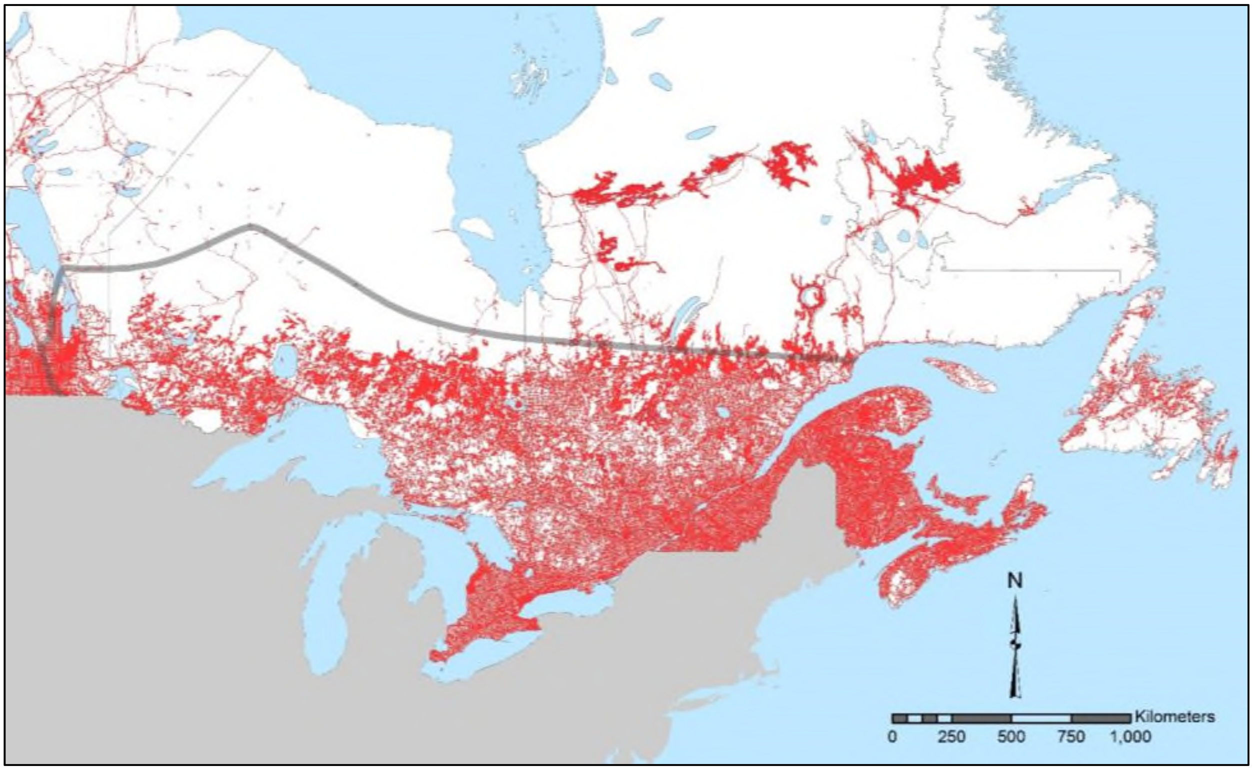

Figure 9. Footprint of industrial disturbance within the range of Black Ash in Canada. Data are from Global Forest Watch (2010). The map shows anthropogenic disturbance from forestry, infrastructure, mines, reservoirs, agriculture, settlement and all other anthropogenic features visible on Landsat imagery (at 28.5 m resolution). The dark grey line shows the northernmost limit of documented Black Ash occurrence.

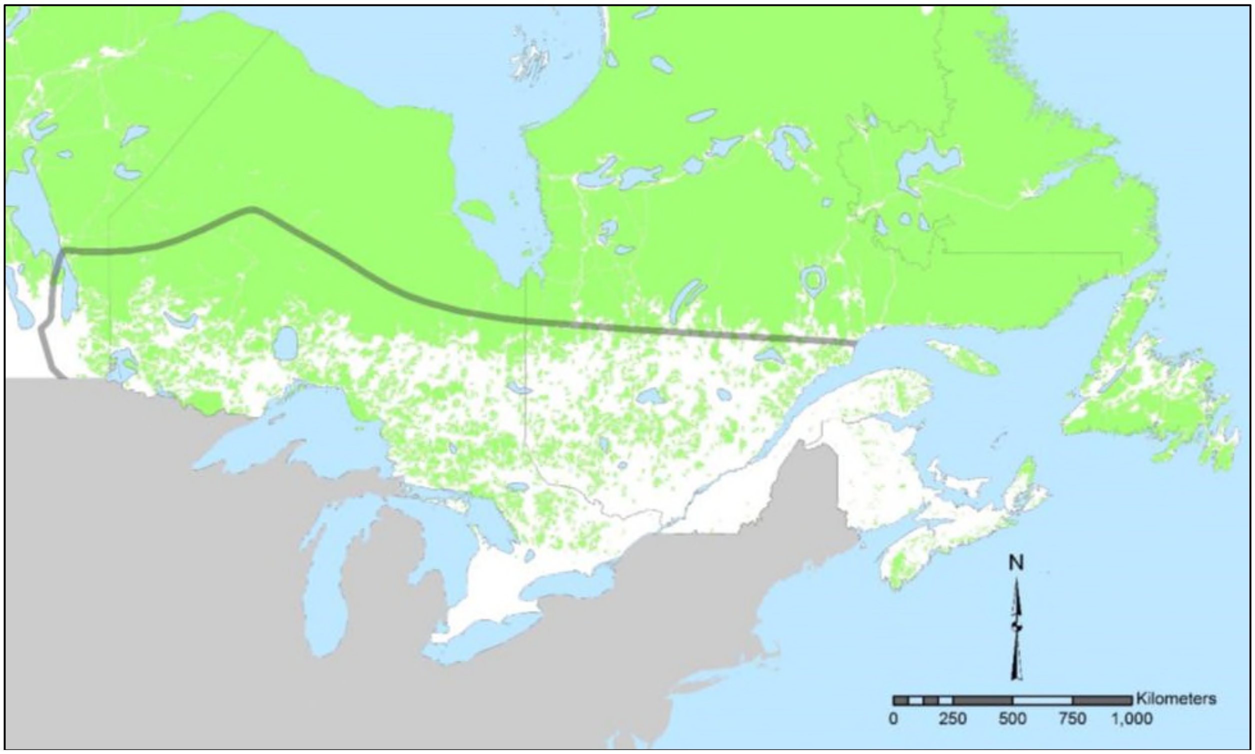

Figure 10. Intact forest landscapes within the range of Black Ash in Canada. Data from Global Forest Watch (2013). The map shows all forest landscape fragments larger than 50 km^2 for the Boreal and Taiga ecozones and fragments larger than 10 km^2 for temperate ecozones. The dark grey line shows the northernmost limit of documented Black Ash occurrence.

There is little published on long-term impacts of industrial forestry on Black Ash populations. Regulations limiting harvesting in wetlands and riparian zones would mitigate forestry effects on Black Ash. The species' high capacity for regeneration from abundant seed production and stump sprouting (see *Biology*) also suggests some level of resilience to the effects of forest harvesting, and fairly high seedling densities have been reported following clearcutting (Peterson 1989). Jackson *et al*. (2000) report a decline of Black Ash over a large area of Algoma District, Ontario between 1857 and 1995, with the cause speculated to be forestry impacts, though their sample size was too small to assess statistical significance. Roy *et al*. (2000) also showed that in clearcut forested wetlands in Quebec, Black Ash can be replaced by pioneer hardwood species such as Trembling Aspen (*Populus tremuloides*) and White Birch (*Betula papyrifera*). Erdmann *et al*. (1987) note that on organic hydric soils, clearcutting or strip cutting often results in poor Black Ash regeneration due to rising water tables and competition from early successional woody species and herbs.

Wood and Pulp Plantations (IUCN Threat 2.2)

Any forest stands treated to inhibit broad-leaved species such as Black Ash are considered under this IUCN threat title, although many such stands would not be considered plantations by foresters.

Conifers such as Black Spruce (*Picea mariana*) represent the dominant commercial species throughout most of Black Ash's Canadian range (Thompson and Pitt 2011). In Ontario, Quebec and New Brunswick, conifer planting and seeding activities are annually carried out over more than 1,000 km^2 (NRCAN 2013, 2014, 2015), roughly equivalent to 0.1% of the species' Canadian range. Much of this would be within habitats in which Black Ash is rare or absent, but conversion of moist mixed or deciduous forest, in which Black Ash is relatively common, to conifer plantations is a factor in some parts of the species range, perhaps most significantly in northern New Brunswick, which supports relatively high Black Ash density and some of the most heavily forestry-altered landscapes in North America (Etheridge *et al*. 2005, 2006; Montigny and MacLean 2005). Although now regulated on Crown land, conversion of Black Ash habitat to conifer plantations is still commonly occurring on industrial freehold land in New Brunswick (Blaney and Mazerolle pers. obs. 1999-2017).

Even without additional management, the high-density planting of conifer seedlings in cut-over areas could impact Black Ash regeneration through competition. It is, however, human suppression of less commercially valuable species that is expected to represent the largest impact of commercial forestry, especially the large-scale application of herbicide to control broad-leaved species. Herbicide treatment is a common forest management practice throughout the Canadian range of Black Ash, with the exception of Quebec, where a provincial ban on forest herbicide use on public lands was enacted in 2001 (Kopra 2006). Glyphosate has accounted for more than 90% of all forestry herbicide use in recent decades (Thompson and Pitt 2011). It is a versatile non-selective synthetic herbicide that kills plants by inhibiting amino acid production (Dill *et al*. 2010). Data provided by national and provincial forestry agencies indicate that in 2014 at least 600 km^2 were treated with herbicide within the core range of Black Ash (NFD 2016). This value may greatly underestimate actual usage given that Thompson and Pitt (2011) report an annual treatment of roughly 700 km^2 in Ontario alone. Although there is little documentation of the specific impact of glyphosate on Black Ash, the herbicide is known to be very effective in controlling other ash species (Willoughby 1999; Dugdale *et al*. 2014).

In harvested areas where Black Ash is present, mechanical site preparations (discing or manual clearing) implemented prior to planting and sowing, as well as subsequent pre-commercial stand thinning may also reduce Black Ash's potential for regeneration by damaging sprout-producing stumps, seedlings and saplings.

<u>Other Habitat Conversion (IUCN Threats 1.1 Housing & urban areas, 1.2 Commercial & industrial areas, 2.1 Annual and perennial non-timber crops, 3.2 Mining & quarrying, 3.3 Renewable energy, 4.1 Roads & railroads, 4.2 Utility & service lines, 7.2 Dams & water management)</u>

As discussed in *Population Trends* and *Habitat Trends*, habitat conversion has significantly reduced Black Ash subpopulations in agricultural and urbanized regions from historical levels and has caused local losses elsewhere.

Habitat conversion resulting in local loss of individuals is continuing and may have significant regional effects into the future on the few remaining Black Ash in areas heavily converted to agricultural and urban land use and impacted by Emerald Ash Borer. It is not, however, expected to be a critical threat at the national scale. The current rate of loss in Canada from the habitat conversion factors in the subheading above is believed to be small (well under 1% per year), with total loss compounded over 60 years (one generation) unlikely to exceed 15% of Black Ash habitat if current rates continue.

White Tailed Deer (IUCN Threat 8.1 Invasive Non-native Species)

Browsing by White-tailed Deer (*Odocoileus virginianus*) is considered a natural limiting factor within the Canadian range, except for Anticosti Island, Quebec, where deer are introduced and extremely abundant. Although deer may be significantly affecting Black Ash in some other areas of Canada (such as the highly fragmented woodlots of the Lake Erie region of Ontario, where they were considered a threat to Blue Ash [COSEWIC 2014]), deer have not been identified as a significant factor over most of the Canadian range.

Since their introduction to Anticosti Island in 1896, White-tailed Deer have proliferated in the absence of natural predators to densities at or above 20 individuals per square kilometre (Potvin and Breton 2005; Levy 2006). Over-browsing by the deer population is known to have profoundly altered the island's ecosystems and now represents a significant challenge for forest resource and biodiversity managers (Potvin *et al*. 2003; Levy 2006).

Black Ash is commonly heavily browsed by White-tailed deer (Erdmann *et al*. 1987; White 2012; Wagner and Todd 2015) and can withstand moderate to heavy winter browsing (Erdmann *et al*. 1987). Bressette *et al*. (2012) document evidence of Black Ash suppression by deer browsing in Virginia, and White (2012) notes severe reduction in recruitment in Minnesota associated with deer browsing. Given the well documented impact of over-browsing on Anticosti Island's plant diversity, forest composition and regeneration (Potvin *et al*. 2003; Casabon and Pothier 2007), it is likely that the island's Black Ash subpopulation has been affected. Black Ash is noted as localized or locally common on Anticosti Island in historical botanical descriptions (Despecher 1895; Schmitt 1904; Marie-Victorin 1935; Rousseau 1974), but the fact that only two current records of single trees in areas protected from browsing could be documented (Pellerin pers. comm. 2017; Tremblay pers. comm. 2017) indicates current rarity, likely caused by intensive deer browsing. Although significant on Anticosti Island, suppression by introduced deer is clearly a trivial effect on the Canadian population given the relative size of Anticosti Island (less than 0.7% of Canadian range).

Moose (IUCN Threat 8.1 Invasive Non-native Species)

Moose browsing is considered a natural limiting factor rather than a threat, except on the Island of Newfoundland, where Moose (*Alces americanus*) were introduced in 1904 on the island's western coast (Pimlott 1959; McLaren *et al*. 2004). Faced with limited natural predation, Moose colonized the entire island by the late 1940s (Pimlott 1959; Caines and

Deichmann 1989) and are now likely significantly affecting Black Ash population and recruitment. Based on range (Figure 3) and observed densities (AC CDC 2016), however, the Newfoundland population of Black Ash represents a very small proportion of the national total, and the effects of introduced Moose are not believed to be a significant threat at the national scale.

Forestry practices during the last 100 years have provided an abundance of prime, early successional Moose habitat (NLDEC 2015) in Newfoundland. Populations peaked in the 1950s and late 1990s (estimated peak of ~150,000 individuals), with the most recent estimate being 112,000 individuals (NLDEC 2015). Presently, Moose occupy all ecoregions on the island at densities commonly exceeding 4/km^2, the highest known in North America (McLaren *et al*. 2004). In Gros Morne National Park and a few other areas within the provincial range of Black Ash, densities as high as 14.6/km^2 have been observed (McLaren *et al*. 2000).

The impact of Moose over-browsing on hardwood and deciduous shrub regeneration in Newfoundland forests is well documented (Dodds 1960; Bergerud and Manuel 1968; McLaren *et al*. 2004). Observations in Terra Nova National Park show that Moose can almost completely remove hardwoods such as Red Maple (*Acer rubrum*) and mountain ash (*Sorbus americana* and *S. decora*) from forest understories and significantly curtail regeneration (McLaren *et al*. 2004). Observations of intensive browsing significantly impacting the vigour of sapling Black Ash are known in Gros Morne National Park (Wentzell pers. comm. 2017) and from Cape Breton Highlands National Park in Nova Scotia (where Moose are native but where exceptionally high populations have also dramatically altered vegetation, eliminating forest regeneration over large areas; Blaney and Mazerolle pers. obs. 1999-2017; Smith *et al*. 2010). Given its known severity and prevalence throughout insular Newfoundland, over-browsing has almost certainly affected Black Ash to some degree and presently represents the most immediate threat to the provincial subpopulation.

<u>Targeted Harvesting (IUCN Threat 5.2 Gathering terrestrial plants; 5.2.1 Intentional use)</u>

Targeted harvesting of Black Ash for barrel making may have been locally significant in the past (Hill-Forde 2004) and harvest for basketry, canoe ribs, snowshoe framing, firewood and other uses still occurs but is not believed to be significantly affecting populations at a national scale.

Traditional Black Ash basketry is an important historical and contemporary cultural practice for First Nations living within the range of the species (see *Special Significance*). Good “basket trees” are those having vigorous growth (2-3 mm thick annual rings), a minimum of 12.5 cm diameter at breast height, a minimum butt log length of 2 m, good crown form and few obvious defects (Benedict and Frelich 2008; Diamond and Emery 2011). Only 1-20% of Black Ash trees are typically suitable for basket making (Benedict and Frelich 2008; Diamond 2009). Because basket-quality trees represent mature, healthy, reproductive individuals, their harvest could limit the potential for regeneration and eliminate individuals potentially resistant or tolerant to EAB or other pests in areas such as Nova Scotia, Prince Edward Island and southeast New Brunswick, where occurrences are sparse and few trees are healthy and reproductive (Hurlburt 2013; Blaney and Mazerolle pers. obs. 1999-2017). In Nova Scotia, however, harvest of Black Ash is probably now quite limited because of its infrequency and low quality and most basketry is done using local White Ash or imported Black Ash logs from Maine and New Brunswick (Hurlburt 2013). As EAB makes its way eastward, imported logs may become unavailable and harvest pressure on local populations could increase.

Ash is generally regarded as a high quality firewood (Alden 1994) and would be targeted as such in private woodlots throughout the species' range, particularly where it occurs in more accessible upland forest habitats. Public awareness of EAB may have the unintended consequence, potentially beyond the range of EAB, of driving private landowners to actively target and cut down ash trees before they become infested and lose their value.

Limiting Factors

Presumed or potentially native pathogens are here classified as limiting factors rather than threats, as is an incompletely explained phenomenon called "ash dieback".

Ash Dieback

"Dieback" refers to mortality of branches, beginning in twigs and gradually proceeding toward the trunk. In this report, the term "ash dieback" refers to ash declines not known to be directly related to insect damage or disease, though those factors, along with climate change, may be significant contributors to the dieback.

Black Ash was originally brought forward for assessment by the COSEWIC Aboriginal Traditional Knowledge Subcommittee because of concerns from elders about observed declines in its health (COSEWIC ATK Subcommittee 2015). General decline of ash health and abundance has been noted in western literature as early as the 1920s (Pomerleau 1944; Woodcock *et al*. 1993; Benedict and David 2000; Palik *et al*. 2011, 2012). Black Ash dieback is widely reported but incompletely understood, and has been associated with drought, excessive soil moisture, winter root kill, late spring frosts, and air pollution (Tardif and Bergeron 1997; Ward *et al*. 2006; Auclair *et al*. 2010; Palik *et al*. 2012). Auclair *et al*. (2010) proposed that ash dieback is mainly a result of winter injury to roots associated with erratic winter weather. In northern hardwoods, root systems are typically shallow and remain active during the winter season, making them vulnerable to freezing if snowpack is insufficient to provide protection from deep frost (Skilling 1964; Sakai and Larcher 1987; Auclair *et al*. 2010). Frost-caused root kill can then exacerbate the effects of drought in the following growing season (Auclair *et al*. 1992). In Maine, documented episodes of Black Ash dieback show a relation to freezing and drought stress, with most documented episodes coinciding with the occurrence of severe soil frosts (Livingston and White 1997; Auclair *et al*. 2010); however, Castello *et al*. (1985) found that drought was only a factor in half of all severe dieback years in New York from 1942 to 1980. Across 21 Black Ash stands in northern Minnesota, frequency of declining individuals ranged from 20% to >60% (Palik *et al*. 2011). Greater dieback was found in wetter sites with a greater depth to mineral soil, and in sites closest to roads (Ward *et al*. 2006; Palik *et al*. 2011). The higher incidence of decline near roads may relate to altered hydrology (i.e. impoundment), road salt runoff and spray, or vehicle emissions (Ward *et al*. 2006). Black Ash decline was also found to be positively correlated with stand age and tree diameters, which may simply be a result of cohort senescence (Palik *et al*. 2011).

There are few quantitative assessments of ash dieback, but declines can be significant. Dieback-related Black Ash losses have been documented over 50,000 ha in Maine (75% of the state's elm - ash - Red Maple forest), 43,000 ha in New York and 11,000 ha in Minnesota (Ward *et al*. 2006), where several counties have experienced Black Ash mortality of 20-50% (Palik *et al*. 2008). In heavily affected stands, decline and mortality in the sapling layer was correlated with the same condition in canopy trees, suggesting that regeneration may be impacted (Palik *et al*. 2012).

There is little documentation of the phenomenon in Canada, but it may be associated with poor tree health and growth observed in the Maritimes described above, and the proximity of dieback in New York and Maine to the international border suggests that it could be occurring in adjacent Ontario and Quebec. Symptoms of Black Ash dieback were noted in Quebec from 1927 to 1944 (Pomerleau 1944) and Hill-Forde (2004) specifically documented "ash dieback" in Nova Scotian Black Ash. Hill-Forde (2004) reported significant inter-annual variability in dieback in Nova Scotia subpopulations, with a 30% decrease in affected trees between 2001 and 2002. Similar patterns of dieback and recovery were observed in Maine (Trial and Devine 1996) in 1993 and in Minnesota (Palik *et al*. 2011, 2012). Although ash dieback is poorly understood, the large geographic scale and locally high mortality rates documented in the United States suggest it should be considered a threat in Canada. Given the believed link to erratic freeze-thaw cycles and decreased snow cover, its significance could increase under continued climate change (Allen and Breshears 2007), especially in the northern part of Black Ash range.

<u>Native Pathogens</u>

Wright and Rauscher (1990) report a number of fungi frequently associated with trunk rot (*Stereum murrayi*), butt rot (*Armillarea mellea*), heartwood rot (*Polyporus hispidus*), leaf spot (*Mycosphaerella effigurata*), anthracnose (*Gloeosporium aridum*), canker (*Nectria galligena*) and Ash Rust (*Puccinia peridermiospra = P. sparganioides*). The extent to which these fungi affect Black Ash in Canada is not known but could be more significant in subpopulations where health has already declined due to biotic or abiotic factors. Most of these pathogens are also known to affect other ash species.

Ash Rust appears to be contributing to local decline near Fredericton, New Brunswick (Powell and Beardmore 2007). This fungus, which colonizes White, Red and Black Ash, occurs throughout the eastern United States (Kaur *et al*. 2010), and has been reported from Ontario to the Maritimes in Canada. It reproduces and overwinters on its alternate hosts: cordgrasses (*Sporobolus* spp.; formerly *Spartina* spp.) and Saltgrass (*Distichlis spicata*) (Douglas 2008). Rust spores released in spring infect newly emerging ash leaves, petioles and green twigs, occasionally leading to defoliation (Douglas 2008). Repeated severe infections can kill large branches, eventually causing tree mortality (Powell and Beardmore 2007). Forest insect and disease surveys carried out by the Canadian Forest Service detected Ash Rust on Black Ash individuals in southern New Brunswick, Nova Scotia, Prince Edward Island, and Quebec (CFS 2016). It is not known if Ash Rust is causing meaningful decline in the Canadian range, and it has not been observed to be significantly contributing to the low vigour observed in southeastern New Brunswick, Nova Scotia and Prince Edward Island subpopulations (Blaney and Mazerolle pers. obs. 1999-2017).

Ash Yellows is a recently discovered ash disease caused by the phytoplasma '*Candidatus' Phytoplasma fraxini*[6] (Pokorny and Sinclair 1994; Griffiths *et al*. 1999). Phytoplasmas are bacteria lacking cell walls that inhabit plant phloem and insect vectors (Kirkpatrick 1997; Bové and Garnier 1998). Ash Yellows is known only from North America, but the fact that its impacts were not observed until the 1980s suggests it may not be native. This would be similar to Chalara Dieback in Europe and Butternut Canker in North America (Nair *et al*. 1979; Broders and Boland 2011; COSEWIC 2017), in which pathogens were only discovered when severe effects were noted outside their native range. Ash Yellows could also be a native disease overlooked until the 1980s because its symptoms are largely indistinguishable from the effects of drought, flooding or opportunistic fungal parasites (Pokorny and Sinclair 1994). Although best known for its impact on White Ash, the microbial agent of Ash Yellows occurs naturally in at least 12 native and exotic ash species in North America, including Black Ash, as well as in 35 lilac taxa (Sinclair *et al*. 1994, 1996). In Canada, the disease is known from Ontario and Quebec (Sinclair *et al*. 1996; Griffiths *et al*. 1999).

Little is known of the disease cycle of Ash Yellows. The phytoplasma is spread by leafhoppers or other homopteran insects and invades and disrupts the phloem of infected trees, causing slow growth, rootlet necrosis, severe chlorosis, canopy dieback and premature death (Pokorny and Sinclair 1994; Sinclair *et al*. 1996). Symptoms develop within three years after phytoplasmas are detected in the phloem (Pokorny and Sinclair 1994). Diseased ash saplings may die within one or two years after symptoms become apparent, while mature trees can often live ten years or more (Sinclair *et al*. 1994, 1996). The pathogenesis described here applies mainly to observed effects on White Ash. Although Black Ash is a known host of Ash Yellows, the extent to which it can be affected by the disease is not well understood. Difficulties in detecting the bacterial agent and limited research mean its range and prevalence in Canada are poorly known.

An undescribed virus causing mosaic symptoms in Minnesota ash populations was identified by Machado-Caballero *et al*. (2013), and it is also uncertain whether this virus is native and previously overlooked or is introduced. The virus was initially identified in White Ash and named White Ash Mosaic Virus but has since been noted in Black Ash showing signs of dieback, both on trees with mild mosaic symptoms (irregularly mottled leaves) and on asymptomatic trees (Machado-Caballero *et al*. 2013). The virus may be one of several

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6 There is no formal taxonomy of phytoplasmas (bacteria that lack a cell wall in the class Mollicutes). Phytoplasmas can only occur within other cells, which prevents the description of species' properties in pure culture required for assignment of binomial Latin names. The nomenclatural convention is to use the "generic" name Phytoplasma preceded by 'Candidatus' (meaning candidate) and to separate into putative species any phytoplasmas with nucleotide sequence similarities less than or equal to 97.5% of known "species" (Phytoplasma Resource Centre 2017).

causal factors contributing to general Black Ash dieback in that state and elsewhere. The incidence and potential impact of the virus within the global and Canadian range of Black Ash are unknown.

Another disease regularly observed in the field is deformation of the female flowers, likely caused by the eriophyid Cauliflower Gall Mite (*Aceria fraxinivorus*, =*Eriophyes fraxinivorus*; Morton Arboretum 2017), which prevents seed formation. The disease organism occurs in Europe (i.e. Redfern and Shirley 2002) and thus could have been introduced in Canada, but no direct comment on whether it is native to North America could be found. Frequency and effects of these galls in wild Black Ash are unknown, but the gall has been observed in both Ontario and New Brunswick Black Ash (Blaney and Mazerolle pers. obs. 1999-2017).

The wide variety of vertebrate and invertebrate ash herbivores described under *Interspecific Interactions* is also likely limiting for Black Ash to some degree.

Number of Locations

Number of locations cannot be precisely quantified but may be best considered to be in the hundreds or thousands. Low minimum temperatures are expected to offer some protection from EAB in areas in which EAB-experienced minimum temperatures average below -30°C (Figure 7). Under current climate conditions, locations in these areas are defined based on threats at the scale of a forestry cut-block or small land parcel, resulting in a high number of locations across the northern margin of Black Ash range. Some portion of those locations are likely to lose their climatic protection with a warming climate within one Black Ash generation. Under a plausible worst case scenario in which warming removed all climatic protection from EAB (see *Threats – Emerald Ash Borer - Climatic limitation of EAB expansion northward*), all occurrences could be considered to represent as few as two occurrences as outlined below.

All occurrences within the Canadian Food Inspection Agency's Regulated Zone for Emerald Ash Borer (CFIA 2017; Figure 11), plus Quebec City and Edmundston, New Brunswick (added to the regulated zone later in 2017 and 2018 because of discoveries of Emerald Ash Borer; CFIA 2017; 2018) could be considered a single location because they are either already being impacted by Emerald Ash Borer or are at a very high level of threat from Emerald Ash Borer impacts within the next decade, based on known potential natural expansion rates of 20 km per year (Prasad *et al*. 2010) and potential human-assisted expansions much greater than that (DeSantis *et al*. 2013).

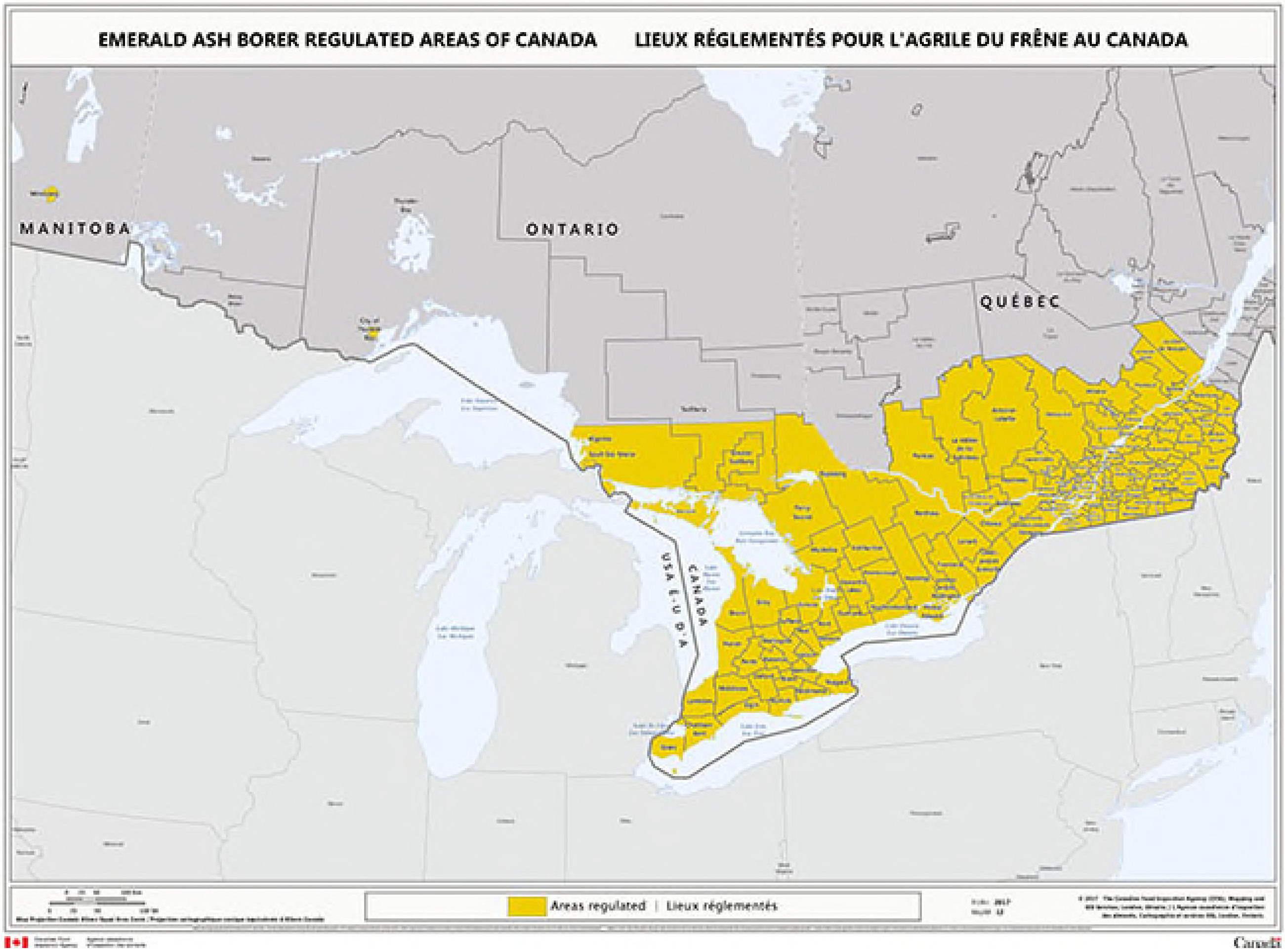

Figure 11. Areas regulated for Emerald Ash Borer in Canada as of March 2017 (CFIA 2017).

For areas outside the regulated zone but well within the climatic tolerance of Emerald Ash Borer (EAB-experienced average annual minimum winter temperature above -30^{o}C; Figure 7), EAB is clearly the most significant threat and all such occurrences could be considered a second location. This is justified because the threat is relatively uniform, given that: a) the known potential natural and human-assisted dispersal rates suggest that EAB could reach all of the Canadian range of Black Ash within one generation (60 years; see *Biology* and *Dispersal and Migration*); and b) once established, EAB has potential to cause massive population loss within Black Ash subpopulations on a time scale much less than one generation (Poland and McCullough 2006; Knight *et al*. 2007; Kovacs *et al*. 2010; Herms and McCullough 2014).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In Nova Scotia, Black Ash was listed under the *Nova Scotia Endangered Species Act* as Threatened in 2013, but it has no provincial or state level legal status in other jurisdictions. The Nova Scotia designation prohibits killing or injuring the species, possessing it for sale or trade, or contravening any regulations regarding core habitat, unless one is in possession of a permit, and it requires the provincial minister to appoint a recovery team and prepare a recovery plan within two years of listing (Nova Scotia Legislature 2017), which recommends a course of action for the species' recovery and core habitat for protection. This was completed by the recovery team in 2015 (Hurlburt 2015).

In Ontario, under the *Municipal Act* (2001) all municipalities below the provincial level have the authority to regulate loss of forest cover and cutting of trees through forest protection or tree-cutting bylaws and many have done so, especially along the Oak Ridges Moraine (OMNR 2005). Black Ash is also protected to some extent in each jurisdiction in which it occurs by regulations enacted under provincial forestry acts that limit harvest along watercourses and by wetland protection acts that limit wetland conversion. In Quebec, the most recent iteration of the provincial *Politique de protection des rives, du littoral et des plaines inondables*, adopted in 2005 and last amended in 2014, regulates the human disturbance of riparian bands (10-15 m in width depending on slope), allowing a maximum harvest/removal of 50% of trees measuring ≥10 cm DBH (Quebec Legislature 2017). This policy provides opportunities for municipalities to relax regulations upon the presentation and provincial approval of a watercourse management plan.

Non-Legal Status and Ranks

Black Ash currently has a global status rank of G5 (Secure) that dates from 1984 (NatureServe 2017) and thus does not reflect the significant threat posed by Emerald Ash Borer. In reviewing the NatureServe ranks below, it is important to understand that many national or subnational status ranks for Black Ash have not been revised to reflect existing and potential impacts of Emerald Ash Borer and thus may not present an accurate picture of its current or near-future status. Black Ash is ranked as secure or potentially secure in Canada (N5) and the United States (N5?). Status ranks of conservation concern (S1 to S3) were assigned prior to the arrival of EAB in eleven peripheral or small jurisdictions (Enns pers. comm. 2017; Ormes pers. comm. 2017), indicating that the conservation concern is based on other factors. These are: SH (Historic) in the District of Columbia, S1S2 (Imperiled) in Nova Scotia, Delaware, North Dakota and Rhode Island, S2 (Imperiled) in Prince Edward Island, S2S3 (Imperiled to Vulnerable) in West Virginia and Manitoba, and S3 (Vulnerable) in the Island of Newfoundland, Maryland and Virginia. In Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Vermont, Massachusetts and New Hampshire, Black Ash is not ranked (SNR). The species is or was widespread in all these jurisdictions, so the SNR rank indicated a lack of concern at the time of ranking, generally prior to EAB. Black Ash is ranked Apparently Secure (S4) in Iowa, New Jersey and Ontario (revised from S5 to S4S5 in 2013 and then to S4 in 2016 because of EAB), Apparently Secure to Secure (S4S5) in New Brunswick, Questionably Secure (S5?) in Quebec, and Secure (S5) in New York and Pennsylvania.

Habitat Protection and Ownership

Across its Canadian range, Black Ash is widespread on provincial and federal Crown land and occurs in hundreds of provincial parks, conservation areas, public and non-governmental nature reserves, and other lands managed fully or partially for conservation. The occurrence data collected for the preparation of this report includes records in over 150 Canadian federal or provincial protected natural areas in Canada, and Black Ash likely occurs in a large majority of all protected lands within its Ontario, Quebec and New Brunswick range. Ontario Parks has occurrence data from 97 sites (McCaul pers. comm. 2017), and Black Ash is documented from 14 National Parks and four National Historic Sites (Nantel pers. comm. 2018). Emerald Ash Borer is known from eight of these sites: Bruce Peninsula, Georgian Bay Islands, Niagara National Historic Sites, Point Pelee, Rideau Canal National Historic Site, Rouge National Urban Park, Thousand Islands, and Trent-Severn Waterway National Historic Site (Nantel pers. comm. 2018). Black Ash would also occur on most First Nations lands within its Canadian range, excepting areas heavily built upon or already heavily affected by Emerald Ash Borer, and excepting some First Nations lands in Manitoba, Nova Scotia and Prince Edward Island where Black Ash is uncommon.

Management for general conservation purposes provides minimal protection against the impacts of Emerald Ash Borer, as the intensive effort required to inoculate individual trees against the beetle is impractical for large scale application (Herms *et al*. 2014b).

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INFORMATION SOURCES

AC CDC (Atlantic Canada Conservation Data Centre). 2017. Black Ash occurrence data. Digital database, Atlantic Canada Conservation Data Centre, Sackville NB. [exported January 2017]

Ahlgren, C.E. 1957. Phenological observations of nineteen native tree species in northeastern Minnesota. Ecology. 38(4):622-628.

Alberto, F.J., S.N. Aitken, R. Alia, S.C. Gonzalez-Martinez, H. Hanninen, A. Kremer, F. Lefevre, T. Lenormand, S. Yeaman, R. Whetten, and O. Savolainen. 2013. Potential for evolutionary responses to climate change – evidence from tree populations. Global Change Biology 19: 1645–1661. doi: 10.1111/gcb.12181

Alden, H.A. 1994. Wood Technology Transfer Fact Sheet: *Fraxinus* spp. Centre for Wood Anatomy Research. USDA Forest Service, Forest Products Laboratory. Madison WI. 3 pp.

Aldous, S.E. 1952. Deer browse clipping study in the Lake States Region. Journal of Wildlife Management. 16(4):401-409.

Allen, C.D., and D.D. Breshears. 2007. Climate-induced forest dieback as an emergent global phenomenon. Eos Transactions. American Geophysical Union. 88(47):504-504.

American Forests. 2012. 2012 National Register of Big Trees. American Forests, Washington D.C. 76 pp. Web site: https://www.americanforests.org/wp-content/uploads/2012/04/BT-Register-PDF_FINAL_web.pdf [accessed January 2017]

APG (Angiosperm Phylogeny Group). 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society. 181:1-20. Web site: http://dx.doi.org/10.1111/boj.1238

APHIS (Animal and Plant Health Inspection Service). 2016. US national Emerald Ash Borer occurrence database. [received from Douglas Bopp, Geographer, US Department of Agriculture – Animal Plant Health Inspection Service, in May 2016]

Arévalo, J.R., J.K. DeCoster, S.D. McAlister, and M.W. Palmer. 2000. Changes in two Minnesota forests during 14 years following catastrophic windthrow. Journal of Vegetation Science. 11(6):833-840.

Aubin, I., F. Cardou, K. Ryall, D. Kreutzqeiser, and T. Scarr. 2015. Ash regeneration capacity after Emerald Ash Borer (EAB) outbreaks: Some early results. The Forest Chronicle. 91(3):291-298

Auclair, A.N.D., R.C. Worrest, D. Lachance, and H.C. Martin. 1992. Climatic perturbation as a general mechanism of forest dieback. In: Manion, P.D. and D. Lachance (Eds). Forest Decline Concepts. American Phytopathological Society Press, St. Paul, MN. pp. 38-58.

Auclair, A.N., W.E. Heilman, and B. Brinkman. 2010. Predicting forest dieback in Maine, USA: a simple model based on soil frost and drought. Canadian Journal of Forest Research. 40(4):687-702.

Ayres, M.P., and M.J. Lombardero. 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Science of the Total Environment. 262(3):263-286.

Bacles, C.F., A.J. Lowe and R.A. Ennos. 2006. Effective seed dispersal across a fragmented landscape. Science. 311:628-628.

Ballard, M. pers. comm. 2017. June 22, 2017. Email communication by Myrle Ballard to Neil Jones (COSEWIC Scientific Project Officer & Aboriginal Traditional Knowledge Coordinator), provided to Sean Blaney. COSEWIC Aboriginal Traditional Knowledge Subcommittee Representative to the Vascular Plants Subcommittee and Ph.D. in the study of flooding impacts on the Aboriginal community of Lake St. Martin. Winnipeg, MB.

Baskin C.C., and J.M. Baskin. 1998. Seeds: ecology, biogeography and evolution of dormancy and germination. Academic Press, San Diego CA. 666 pp.

Bauer, L.S., J.J. Duan, J.G. Gould, and R.G. Van Driesche. 2015. Progress in the classical biological control of *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) in North America. Can. Entomol. 147, 300–317. Web site: http://dx.doi.org/10.4039/ tce.2015.18.

Beasley, R.R., and P.M. Pijut. 2010. Adventitious shoot regeneration of *Fraxinus nigra* Marsh. United States Forest Service Northern General Technical Department of Research Station Report NRS-P-72 Agriculture. 9:58. Poster presentation. Web site: https://htirc.org/wp-content/themes/child_theme/assets/pdf/Beasley.pdf [accessed May 2016]

Beasley, R.R., and P.M. Pijut. 2013. Regeneration of Plants from *Fraxinus nigra* Marsh. hypocotyls. HortScience. 48(7):887-890.

BenDor, T.K., S.S. Metcalf, L.E. Fontenot, B. Sangunett, and B. Hannon. 2006. Modeling the spread of the emerald ash borer. Ecological Modeling. 197(1):221-236.

Benedict, L., and R. David. 2000. Handbook for Black Ash Preservation, Reforestation/Regeneration Mohawk Council of Akwesasne, Department of Environment.

Benedict, L., and R. David. 2003. Propagation protocol for Black Ash (*Fraxinus nigra* Marsh.). Native Plants Journal. 4(2):100-103.

Benedict, M.A., and L.E. Frelich. 2008. Site factors affecting Black Ash ring growth in northern Minnesota. Forest Ecology and Management. 255:3489-3493.

Benedict, M.A. 2001. Black Ash: Its use by Native Americans, site factors affecting seedling abundance and ring growth in northern Minnesota. Master's Thesis, Department of Forest Resources, University of Minnesota, St Paul, MN.

Benedict, L. 2011. Coordination of *Fraxinus* Conservation on Tribal and Public Lands. ARS Project Grant Agreement #59-5402-7-345. Akwesasne Task Force on the Environment, Akwesasne QC. 8 pp. Web site: https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxibGFja2FzaGNlbnRlcnxneDozNGNhMmYyZGQ2MDc2NDdm [accessed January 2017]

Bergerud, A.T., and F. Manuel. 1968. Moose damage to balsam fir-white birch forests in central Newfoundland. The Journal of Wildlife Management. 1968(1):729-746.

Black River First Nation. 2005. Establishment of a Global Warming Bio-Monitoring Program in the Boreal Forest of Eastern Manitoba: Year I. Manitoba Model Forest Report 04-5-06. 93 pp. Web site: http://www.manitobamodelforest.net/publications/Establishment%20of%20a%20Global%20Warming%20Bio-Monitoring%20Program%20Eastern%20Manitob.pdf [accessed February 2014]

Blaney, C.S. pers. obs. 1989-2017. Personal observations on the general biology of Black Ash and on the species' abundance and distribution in Ontario and the Maritimes provinces. Executive Director and Senior Scientist, Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, C.S., and D.M. Mazerolle pers. obs. 1999-2017. Personal observations on the vascular flora of the Maritimes provinces. Executive Director and Senior Scientist (C.S. Blaney), Botanist (D.M. Mazerolle), Atlantic Canada Conservation Data Centre, Sackville NB.

Blaney, S., J. Churchill, R. DeSantis, and D. Gormanson. 2018. Climatic Limitation of Emerald Ash Borer (*Agrilus planipennis*) Impacts on Black Ash (*Fraxinus nigra*) in Canada. Committee on the Status of Wildlife in Canada, Aboriginal Traditional Knowledge Subcommittee, Gatineau, QC. 15 pp.

Bonner, F.T. 1974. *Fraxinus* ash. In: Schopmeyer, C.S. (Ed). Seeds of woody plants in the United States. U.S. Department of Agriculture, Agriculture Handbook 450. Washington, DC. pp. 411-416.

Bopp, D. pers. comm. 2016. May 2016. Email correspondence with D.M. Mazerolle, concerning the documented distribution of Emerald Ash Borer in the United States and Canada. Geographer, Animal and Plant Health Inspection Service, United States Department of Agriculture, Brighton MI.

Bové J.M., and M. Garnier. 1998. Walled and wall-less eubacteria from plants: sieve-tube-restricted plant pathogens. Plant Cell, Tissue and Organ Culture 52:7-16

Brand, G.J. 1985. Environmental indices for common Michigan trees and shrubs. Res. Pap. NC-261. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 5 pp.

Brasier, C.M. 1991. *Ophiostoma novo-ulmi* sp. nov., causative agent of current Dutch elm disease pandemics. Mycopathologia. 115:151-161.

Bressette, J.W., H. Beck and V.B. Beauchamp. 2012. Beyond the browse line: complex cascade effects mediated by white-tailed deer. Oikos. 121:1749-1760. doi: 10.1111/j.1600-0706.2011.20305.x

Broders, K.D. and G.J. Boland. 2011. Reclassification of the Butternut canker fungus, *Sirococcus clavigignenti-juglandacearum*, into the genus *Ophiognomonia*. Fungal Biology. 115:70-79.

Brownell, V.R. pers. comm. 2017. February 2017. Email correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash in Ontario and Quebec. Species at Risk Biologist, Species at Risk Conservation Branch, Ontario Ministry of Natural Resources and Forestry, Peterborough ON.

Brouillet, L., F. Coursol, S.J. Meades, M. Favreau, M. Anions, P. Bélisle, and P. Desmet. 2010+. VASCAN, the Database of Vascular Plants of Canada. Web site: http://data.canadensys.net/vascan/ [accessed February 2017]

Brinker, S., pers. comm. 2017. February 2017. Email correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash in Ontario and Quebec. Project Botanist, Ontario Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry, Peterborough ON.

Brunton, D., pers. comm. 2017. February 2017. Email correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash in Ontario and Quebec. Professional botanist, Ottawa ON.

Buck, J., G. Parra, D. Lance, R. Reardon, and D. Binion (Eds.). 2014. 2014 Emerald Ash Borer National Research and Technology Development Meeting. Ohio Agricultural Research and Development Center, Wooster OH. October 15-56, 2014.

Burr, S.J., and D.G. McCullough. 2014. Condition of green ash (*Fraxinus pennsylvanica*) overstory and regeneration at three stages of the emerald ash borer invasion wave. Canadian Journal of Forest Research. 44(7):768-776.

Caines, P., and H. Deichmann. 1989. Resource Description and Analysis: Gros Morne National Park. Gros Morne National Park, Parks Canada, Rocky Harbour, NL.

Canadensys. 2016. Specimen database. Database of Vascular Plants of Canada. Web site: http://explorer.canadensys.net/occurrences/search?taxa=fraxinus+nigra [accessed May 2016]

Canadian Hydropower Association. 2017. Hydropower Potential. Web site: https://canadahydro.ca/hydropower-potential/ [accessed February 8, 2017]

Cappaert, D., D.G. McCullough, T.M. Poland, and N.W. Siegert. 2005. Emerald ash borer in North America: a research and regulatory challenge. American Entomologist. 51:152-165.

Carmean, W.H. 1978. Site index curves for northern hardwoods in northern Wisconsin and Upper Michigan. USDA Forest Service, Research Paper NC-160. North Central Forest Experiment Station, St. Paul MN. 16 pp.

Casabon, C., and D. Pothier. 2007. Browsing of tree regeneration by white-tailed deer in large clearcuts on Anticosti Island, Quebec. Forest Ecology and Management. 253(1):112-119.

Castello, J.D., S.B. Silverborg, and P.D. Manion, P.D. 1985. Intensification of ash decline in New York State from 1962 through 1980. Plant Disease. 69(3):243-246.

CEPI (Collaborative Environmental Planning Initiative). 2006. Bras d'Or Lakes Traditional Ecological Knowledge Workshop Proceedings, May 3-4, 2006. Unama'ki Institute of Natural Resources, Eskasoni, Nova Scotia.

CFIA (Canadian Food Inspection Agency). 2017. Areas currently regulated for Emerald Ash Borer. Web site: http://www.inspection.gc.ca/DAM/DAM-plants-vegetaux/STAGING/text-texte/pestrava_agrpla_ministerial_pdf_1337372111445_eng.pdf [accessed May 2018]

CFIA (Canadian Food Inspection Agency). 2018. Emerald Ash Borer – Latest Information. Web site: http://www.inspection.gc.ca/plants/plant-pests-invasive-species/insects/emerald-ash-borer/latest-information/eng/1337287614593/1337287715022 [accessed September 2018]

CFS (Canadian Forest Service). 2016. National Tree Seed Centre seed lot database and Forest Insect and Disease Survey database. Canadian Forest Service, Fredericton, NB. [received from Dale Simpson, Manager, National Tree Seed Centre in May 2016]

City of Calgary. 2017. Cottony Ash Psyllid. Web site: http://www.calgary.ca/CSPS/Parks/Pages/Planning-and-Operations/Pest-Management/Cottony-ash-psyllid.aspx [accessed on February 2017]

City of Edmonton. 2017. Cottony Psyllids on Ash. Web site: https://www.edmonton.ca/programs_services/pests/cottony-psyllids-on-ash.aspx [accessed February 2017]

City of Saskatoon. 2013 Cottony Ash Psyllid (*Psyllopsis discrepans*). Pest Fact Sheet. City of Saskatoon, Parks Branch. 1 p. Web site: http://www.saskinvasives.ca/file/Cottony_Ash_Psyllid_Fact_Sheet.pdf [accessed February 2017]

City of Windsor. 2017. Urban Forest. Web site: http://www.citywindsor.ca/residents/parksandforestry/urban-forest/pages/urban-forest.aspx [accessed January 2017]

Colman-Sadd, S.P., J.P. Hayes, and I. Knight.1990. Geology of the Island of Newfoundland. Map 90-01. Scale: 1:1,000,000. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch. GS# NFLD/2192.

COSEWIC ATK Subcommittee. 2015. ATK Assessment Report on Black Ash (*Fraxinus nigra*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa ON.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2010. COSEWIC Guidelines on Manipulated Populations. Committee on the Status of Endangered Species in Canada. Website: http://www.cosewic.gc.ca/eng/sct2/sct2_8_e.cfm [accessed June 2016].

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2014. COSEWIC assessment and status report on the Blue Ash *Fraxinus quadrangulata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa ON. xiii + 58 pp.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2015a. Instructions for the Preparation of COSEWIC Status Reports. Committee on the Status of Endangered Wildlife in Canada. 36 pp. Web site: http://www.cosewic.gc.ca/default.asp?lang=En&n=ED199D3B-1&offset=2&toc=show [accessed January 2017]

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2015b. COSEWIC assessment and status report on the Flooded Jellyskin *Leptogium rivulare* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 48 pp.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2017 (draft). COSEWIC assessment and update status report on Butternut (*Juglans cinerea*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxv + 70 pp.

Compton, S.G. 2002. Sailing with the wind: dispersal by small flying insects. Chapter 6 In: Dispersal Ecology: 42nd Symposium of the British Ecological Society, J.M. Bullock, R.E. Kenward & R.S. Halls (Eds.). Blackwell Science, Malden MA. 480 pp.

CMH (Connell Memorial Herbarium). 2016. Online specimen database. Web site: http://unbherbarium.ca/ [accessed May 2016]

Craft, K.J., and M.V. Ashley. 2007. Landscape genetic structure of Bur Oak (*Quercus macrocarpa*) savannas in Illinois. Forest Ecology Management. 239:13-20.

Crosthwaite, J.C., S. Sobek, D.B. Lyons, M.A. Bernards, and B.J. Sinclair. 2011.The over-wintering physiology of the emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae). Journal of Insect Physiology. 57:166-173.

Culliney, T.W., and A.L. Koop. 2005. Cottony Ash Psyllid, *Psyllopsis discrepans* (Flor) (Homoptera: Psyllidae). US Department of Agriculture, Animal & Plant Health Inspection Service. Center for Plant Health Science & Technology. Pest Fact Sheet 2005-01. 6 p.

Curtis, J.T. 1959. The vegetation of Wisconsin. University of Wisconsin Press. Madison WI. 657 pp.

Davidson, W.C. 2015. Developing a Sustainable Approach to Emerald Ash Borer Management. Masters thesis. University of Kentucky. Theses and Dissertations – Entomology. Paper 21. 88 pp.

Davis, M.B., K.D. Woods, S.L. Webb, and R.P. Futyma. 1986. Dispersal versus climate: Expansion of Fagus and Tsuga into the Upper Great Lakes region. Plant Ecology. 67(2):93-103.

Davidson-Hunt, I.J., P. Jack, E. Mandamin, and B. Wapioke. 2005. A contribution to Anishinaabe (Ojibwe) ethnobotany of northwestern Ontario, Canada: toward a holistic representation of Iskatewizaagegan (Shoal Lake) plant knowledge. Journal of Ethnobiology. 25:189-227.

Dayton, P.K. 1972. Toward an understanding of community resilience and the potential effects of enrichments to the benthos at McMurdo Sound, Antarctica. In: Parker, B.C. (Ed.). Proceedings of the Colloquium on Conservation Problems in Antarctica. Allen Press, Lawrence KS. pp. 81-95.

Denneler, B., Y. Bergeron, and Y. Bégin. 1999. An attempt to explain the distribution of the tree species composing the riparian forests of Lake Duparquet, southern boreal region of Quebec, Canada. Canadian Journal of Botany 77(12):1744-1755.

Denneler, B., H. Asselin, Y. Bergeron, and Y. Bégin. 2008. Decreased fire frequency and increased water levels affect riparian forest dynamics in southwestern boreal Quebec, Canada. Canadian Journal of Forest Research. 38(5):1083-1094.

Densmore, F. 1974. How Indians Use Wild Plants for Food, Medicine and Crafts. Dover Publications Inc., New York.

DeSantis, R.D., W.K. Moser, D.D. Gormanson, M.G. Bartlett, and B. Vermunt. 2013. Effects of climate on emerald ash borer mortality and the potential for ash survival in North America. Agricultural and forest meteorology. 178:120-128.

Despecher, J. 1895. Notice sur l'Île Anticosti par Jules Despecher. Paris. 12 May 1895. 6 pp. Web site: https://www.comettant.com/biblioth%C3%A8que/despecher-anticosti/ [accessed December 2016]

de Vos, A. 1964. Food utilization of snowshoe hares on Mantitoulin Island, Ontario. Journal of Forestry. 62:238-244.

Diamond, A.K. 2009. The art of finding what's needed: Ethnoecological knowledge of basket and dye species in New England. Master's Thesis, Department of Plant Biology, University of Vermont, Burlington, VT.

Diamond, A.K., and M.R. Emery. 2011. Black Ash (*Fraxinus nigra* Marsh.): Local Ecological Knowledge of Site Characteristics and Morphology Associated with Basket-Grade Specimens in New England (USA). Economic Botany. 65(4):422-426.

Dill G.M., R.D. Sammons, P.C.C. Feng, F. Kohn, K. Kretzmer, A, Mehrsheikh, M. Bleeke, J.L. Honegger, D. Farmer, D. Wright, and E.A. Haupfear. 2010. Glyphosate: discovery, development, applications, and properties. In: Nandula V.K. (Ed.). Glyphosate Resistance in Crops and Weeds: History, Development, and Management. Wiley, NY. pp. 1-33.

Dodds, D.G. 1960. Food competition and range relationships of moose and snowshoe hare in Newfoundland. The Journal of Wildlife Management. 24(1):52-60.

Donovan, G.H., D.T. Butry, Y.L. Michael, J.P. Prestemon, A.M. Liebhold, D. Gatziolis, and M.Y. Mao. 2013. The Relationship Between Trees and Human Health Evidence from the Spread of the Emerald Ash Borer. Am. J. Prev. Med. 44:139 –145.

Douglas, S.M. 2008. Ash leaf rust fact sheet. Connecticut Agricultural Experiment Station, Department of Plant Pathology and Ecology. New Haven CT. Web site: http://www.ct.gov/caes/lib/caes/documents/publications/fact_sheets/plant_pathology_and_ecology/ash_leaf_rust_06-23-08r.pdf [accessed February 2017]

Drenkhan, R., H. Sander and M. Hanso. 2014. Introduction of Mandshurian ash (*Fraxinus mandshurica* Rupr.) to Estonia: is it related to the current epidemic on European ash (*F. excelsior* L.)?. European Journal of Forest Research. 133(5):769-781.

Duan, J.J., L.S. Bauer, and R.G. Van Driesche. 2017. Emerald ash borer biocontrol in ash saplings: The potential for early stage recovery of North American ash trees. Forest Ecology and Management 394: 64-72. Web site: http://dx.doi.org/10.1016/j.foreco.2017.03.024 0378-1127

Duan, J.J., L.S. Bauer, K.J. Abell, J. Lelito, and R.G. Van Driesche. 2013. Establishment and abundance of *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in Michigan: potential for success in classical biocontrol of the invasive emerald ash borer (Coleoptera: Buprestidae). J. Econ. Entomol. 106, 1145–1154. http:// dx.doi.org/10.1603/EC13047.

Duan, J.J., L.S. Bauer, R.G. Van Driesche, and J.R. Gould. 2018. Progress and challenges of protecting North American ash trees from the Emerald Ash Borer using biological control. Forests. 9(3):142

Ducks Unlimited. 2010. Southern Ontario Wetland Conversion Analysis: Final Report. March 2010. 23 pp. + appendices.

Dugdale, T.M., T.D. Hunt, and D. Clements. 2014. Controlling desert ash (*Fraxinus angustifolia* subsp. *angustifolia*): have we found the silver bullet?. In: 19th Australasian Weeds Conference - Science, Community and Food Security: the Weed Challenge. Tasmanian Weed Society, September 1-4, Hobart, Tasmania, Australia.

Dukes, J.S., J. Pontius, D. Orwig, J.R. Garnas, V.L. Rodgers, N. Brazee, B. Cooke, K.A. Theoharides, E.E. Stange, R. Harrington, J. Ehrenfeld, J. Gurevich, M. Lerdau, K. Stinson, R. Wick, and M. Ayres. 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? Can. J. For. Res. 39: 231-248. Doi: 10.1139/X08-171

Dynesius, M., and C. Nilsson. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science. 266:4.

Ehrenfeld, J. 2012. Northern Red Maple and Black Ash Swamps. Chapter 11 (p. 149-160), in *Wetland habitats of North America: Ecology and conservation concerns*. D.P. Batzer and A.H. Baldwin (eds.). University of California Press, Berkeley, CA.

Elias, T.S. 1987. The Complete Trees of North America: A Field Guide and Natural History. Gramercy Publishing Company, NY. 948 pp.

Enns, A. pers. comm. 2017. February 2017. Email correspondence with D.M. Mazerolle, concerning subnational status ranks and ranking dates for Black Ash in Canada. National Data Manager, NatureServe Canada, Vancouver BC.

Environment Canada. 2013. Recovery Strategy for the Flooded Jellyskin Lichen (*Leptogium rivulare*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. iv + 23 pp.

Erdmann, G.G., T.R. Crow, R.M. Peterson (Jr.), and C.D. Wilson. 1987. Managing Black Ash in the Lake States. General Technical Report NC-115, St. Paul, MN; United States Department of Agriculture, Forest Service, North Central Forest Experiment Station. 10 pp.

Etheridge D.A., D.A. MacLean, R.G. Wagner, and J.S. Wilson. 2005. Changes in landscape composition and stand structure from 1945–2002 on an industrial forest in New Brunswick, Canada. Can J. For. Res. 35: 1965–1977.

Etheridge D.A., D.A. MacLean, R.G. Wagner, and J.S. Wilson. 2006. Effects of intensive forest management on stand and landscape characteristics in northern New Brunswick, Canada (1945–2027). Landscape Ecology 21: 509–524. DOI 10.1007/s10980-005-2378-9

Farrar, J.L. 1995. Trees in Canada. Canadian Forest Service, Ottawa and Fitzhenry and Whiteside Ltd., Markham ON. 502 pp.

Fauske, G., J. Knott, D. Nelson, and M. Kangas. 2005. Cottony ash psyllid in North Dakota. North Dakota State University Crop & Pest Report 8:1.

FIA (Forest Inventory and Analysis). 2016. Forest Inventory and Analysis 2010-2015 survey plot data. US Department of Agriculture, US Forest Service. [data exported in November 2016]

First Nations Forestry Program. 2006. *An exploration of on-reserve forest management capacity and forest certification interest in First Nations communities across Canada.* Natural Resources Canada, Ottawa, Ontario, Canada.
Web site: http://publications.gc.ca/site/eng/304839/publication.html.

Flowers, C.E., K.S. Knight, and M.A. Gonzalez-Meler. 2013. Impacts of the emerald ash borer (*Agrilus planipennis* Fairmaire) induced ash (*Fraxinus* spp.) mortality on forest carbon cycling and successional dynamics in the eastern United States. *Biological Invasions* 15: 931–944.

Forbes, B.W. 2012. Physical and mechanical property variation of Black Ash (*Fraxinus Nigra* M.) grown in the Thunder Bay seed zone. Master's thesis, Lakehead University, ON. 209 pp.

Fraser, I., V.C. Mastro, and D.R. Lance. 2005. Emerald ash borer dispersal – a release and recapture study. In: Mastro, V.C., R. Reardon and G. Parra (Eds.). Emerald Ash Borer Research and Technology Development Meeting. Forest Health Technology Enterprise Team, Morgantown WV. Pittsburgh PE. September 26-27, 2005. p. 9.

Gandhi, K.J., and D.A. Herms. 2010. North American arthropods at risk due to widespread *Fraxinus* mortality caused by the alien emerald ash borer. Biological Invasions. 12(6):1839-1846.

Gates, F.C. 1942. The bogs of northern Lower Michigan. Ecological Monographs 12:213-254. DOI: 10.2307/1943542, Web site: http://www.jstor.org/stable/1943542

Gavin, D.G., and D.R. Peart. 1993. Effects of beech bark disease on the growth of American beech (*Fagus grandifolia*). Canadian Journal of Forest Research. 23(8):1566-1575.

Gilmore, M.R. 1933. Some Chippewa uses of Plants. Univ. Mich. Press, Ann Arbor, Michigan.

GoBotany. 2017. New England Wild Flower Society`s online plant identification resource. Web site: https://gobotany.newenglandwild.org/ [accessed January 2017]

Godman, R.M., and G.A. Mattson. 1976. Seed crops and regeneration problems of 19 species in northeastern Wisconsin. USDA Forest Service, Research Paper NC-123. North Central Forest Experiment Station, St. Paul MN. 5 pp.

Google Patents. 2017a. Hybrid ash tree named ‘Northern Treasure’ US PP11840 P2. Web site: https://www.google.com/patents/USPP11840 [accessed January 2017].

Google Patents. 2017b. Hybrid ash tree named ‘Northern Gem’ US PP11777 P2. Web site: https://www.google.com/patents/USPP11777 [accessed January 2017].

Gleason, H.A., and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. The New York Botanical Garden. Bronx, New York. 910 pp.

Global Forest Watch. 2010. Canada Access: Combined. A compilation of data sources showing areas that have undergone anthropogenic disturbance. Web site: http://www.globalforestwatch.ca/data/20100913B [accessed May 2016]

Global Forest Watch. 2013. Canada’s Intact Forest Landscapes 2013 Dataset. Web site: http://www.globalforestwatch.ca/node/252 [accessed May 2016

Griffiths, H.M., W.A. Sinclair, C.D. Smart, and R.E. Davis. 1999. The phytoplasma associated with ash yellows and lilac witches'-broom:‘*Candidatus Phytoplasma fraxini*’. International Journal of Systematic and Evolutionary Microbiology. 49(4):1605-1614.

Grimm, E.C. 1962. The Book of Trees. Stackpole, Harrisburg, PA.

Grimm, E.C. 1984. Fire and other factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. Ecological Monographs. 54(3):291-311.

Gucker, C.L. 2005. *Fraxinus nigra*. In: Fire Effects Information System. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Web site: https://www.fs.fed.us/database/feis/plants/tree/franig/all.html [accessed January 2017]

Haack, R.A., E. Jendak, L. Houping, K.R. Marchant, T.R. Petrice, T.M. Poland, and H. Ye. 2002. The emerald ash borer: a new exotic pest in North America. Newsletter of the Michigan Entemological Society. 47(3-4).

Halmschlager, E., and T. Kirisits. 2008. First report of the ash dieback pathogen *Chalara fraxinea* on *Fraxinus excelsior* in Austria. Plant Pathology. 57(6):1177.

Hamel, P.B., and M.U. Chiltoskey. 1975. Cherokee Plants an early Cherokee ethnobotanical note. Herald Publishing Co., Sylva NC.

Handfield, L. 2011. Le guide des papillons du Québec. Broquet, Saint-Constant QC. 982 pp.

Hansen, H.L., L.W. Krefting, and V. Kurmis. 1973. The forest of Isle Royale in relation to fire history and wildlife. Tech. Bull. 294; Forestry Series 13. Minneapolis, MN: University of Minnesota, Agricultural Experiment Station. 44 pp.

Harlow, W.M., and E.S. Harrar. 1979. Textbook of Dendrology: covering the important forest trees of the United States and Canada 5th Ed. McGraw-Hill, NY.

Harris, A., pers. comm. 2017. February 2, 2017. Email communication by Allan Harris to Sean Blaney regarding distribution and frequency of Black Ash in northern Ontario. Biologist, Principal, Northern Bioscience Ecological Consulting, Thunder Bay ON.

Hawboldt, L.S., and R.M. Bulmer. 1958. The forest resources of Nova Scotia. Nova Scotia Department of Lands and Forests. 171 pp.

Heinselman, M.L. 1970. Landscape evolution, peatland types and the environment in the Lake Agassiz Peatlands Natural Area, Minnesota. Ecological Monographs. 40(2):235-261.

Heinselman, M.L. 1981. Fire and succession in the conifer forests of northern North America. In: West, D.C., H.H. Shugart and D.B. Botkin (Eds.). Forest Succession: Concepts and Applications. Springer-Verlag, NY. pp. 374-405.

Hendrickson, J.A. 2012. Genetic variability and inheritance of nuclear microsatellite markers in Minnesota's Black Ash (*Fraxinus nigra*) and Green Ash (*F. pennsylvanica*) with recommendations for the optimal seed sample size from individual trees. Master's thesis. University of Minnesota. Minneapolis, MN. 56 pp. Web site: http://conservancy.umn.edu/bitstream/handle/11299/140944/1/Hendrickson_Julie_October2012.pdf [accessed January 2017]

Herms, D.A., W. Klooster, K.S. Knight, K.J.K. Gandhi, C.P. Herms, A. Smith, D. McCullough, and J. Cardina. 2010. Ash regeneration in the wake of emerald ash borer: will it restore ash or sustain the outbreak?. In: Lance, D., J. Buck, D. Binion, R. Reardon and V. Mastro (Eds.). Emerald Ash Borer Research and Technology Development Meeting. US Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. FHTET-2010-01. pp. 17-18.

Herms, D.A., W. Klooster, K.S. Knight, K.J. Gandhi, A. Smith, C.P. Herms, D. Hartzler, D.G. McCullough, and J. Cardina, 2011. Ash demography in the wake of the Emerald Ash Borer: will regeneration restore ash or sustain the invasion?. In: McManus, K. and K.W. Gottschalk (Eds.). Proceedings of the 22nd US Department of Agriculture Interagency Research Forum on Invasive Species. US Department of Agriculture. General Technical Report NRS-P-92. Annapolis MD. January 11-14, 2011. pp. 27.

Herms, D.A., and D.G. McCullough. 2014. Emerald ash borer invasion of North America: history, biology, ecology, impacts, and management. Annual Review of Entomology. 59:13-30.

Herms, D.A., D.R. Smitley, and B. Cregg. 2014a. Interspecific patterns of ash decline and mortality in a common garden. In: Buck, J., G. Parra, D. Lance, R. Reardon and D. Binion (Eds.). 2014 Emerald Ash Borer National Research and Technology Development Meeting. Ohio Agricultural Research and Development Center, Wooster OH. October 15-56, 2014. p. 38.

Herms D.A., D.G. McCullough, D.R. Smitley, C.S. Clifford, and W. Cranshaw. 2014b. Insecticide options for protecting ash trees from emerald ash borer. North Central IPM Center Bulletin. 2nd Edition. 16 pp. Web site: http://www.extension.umn.edu/garden/insects/find/emerald-ash-borer/docs/ncbipm_eab_insecticide_bulletin_2nd_ed_may_2014.pdf [accessed February 2017]

Herrick, J.W. 1977. Iroquois Medical Botany. PhD Thesis. State University of New York, Albany NY.

Hill-Forde, S. 2004. Change over time in the abundance and distribution of Black Ash in Nova Scotia: Effects of Mi'kmaq traditional use, and recommendations for the best germination technique for province-wide replanting programs. Nova Scotia Agricultural College & Dalhousie University, Truro, Nova Scotia. 114 pp. Web site: http://www.collectionscanada.gc.ca/obj/s4/f2/dsk4/etd/MQ94164.PDF [accessed January 7, 2014]

Hodkinson, I.D. 1988. The Nearctic Psylloidea (Insecta: Homoptera): an annotated check list. Journal of Natural History. 22(5):1179-1243.

Hoffman, W.J. 1891, The Midewiwin or 'Grand Medicine Society' of the Ojibwa, SI-BAE Annual Report #7. 200 pp.

Hosie, R.C. 1979. Native trees of Canada. 8th edition. Fitzhenry & Whiteside Ltd. Publishers, ON. 380 pp.

Hoven, B.M., D.L. Gorchov, and K.S. Knight. 2014. The effect of Emerald Ash Borer-caused tree mortality on forest regeneration. In: 2014 Emerald Ash Borer National Research and Technology Development Meeting. October 2014. p. 30.

Humber, J. pers. comm. 2017. June 29, 2017. Email communication by Jessica Humber to Neil Jones (COSEWIC Scientific Project Officer & Aboriginal Traditional Knowledge Coordinator), provided to Sean Blaney. Ecosystem Management Ecologist, Newfoundland Department of Fisheries & Land Resources, Corner Brook, NL.

Hurlburt, D. 2013. Provincial Status Report on Black Ash (*Fraxinus nigra*). Nova Scotia Department of Natural Resources, Kentville, NS. 38 pp.

Hurlburt, D. (coordinating author). 2015. Recovery and Action Plan for Black Ash (*Fraxinus nigra*) in Nova Scotia. Nova Scotia Department of Natural Resources, Kentville, NS. 41 pp.

IPNI (International Plant Names Index). 2017. The International Plant Names Index. Web site: http://www.ipni.org [accessed January 2017]

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014 - Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press.

IUCN – CMP (International Union for the Conservation of Nature – Conservation Measures Partnership). 2017. Threats Classification Scheme (Version 3.2). Web site: http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme [accessed September 2017]

Iverson, L.R., and A.M. Prasad. 2002. Potential redistribution of tree species habitat under five climate change scenarios in the eastern US. Forest Ecology and Management. 155(1):205-222.

Iverson L.R., A.M. Prasad, S.N. Matthews, and M. Peters. 2008. Estimating potential habitat for 134 eastern US tree species under six climate scenarios. Forest Ecology and Management. 254:390-406.

Iverson, L., K.S. Knight, A. Prasad, D.A. Herms, S. Matthews, M. Peters, A. Smith, D.M. Hartzler, R. Long, and J. Almendinger. 2016. Potential species replacements for Black Ash (*Fraxinus nigra*) at the confluence of two threats: Emerald ash borer and a changing climate. Ecosystems. 19(2):248-270.

Jackson, S.M., F. Pinto, J.R. Malcolm, and E.R. Wilson. 2000. A comparison of pre-European settlement (1857) and current (1981-1995) forest composition in central Ontario. Canadian Journal of Forest Research. 30(4):605-612.

Janssen, C.R. 1984. Modern Pollen Assemblages and Vegetation in the Myrtle Lake Peatland, Minnesota Ecological Monographs 54:213–252.

Johnson, S.E., and D.M. Waller. 2013. Influence of dam regulation on 55-year canopy shifts in riparian forests. Canadian Journal of Forest Research. 43(2):159-170.

Johnston, C.A., and R.J. Naiman. 1990. Browse selection by beaver: effects on riparian forest composition. Canadian Journal of Forestry Research. 20:1036-1043.

Julien, F. 2013. Mi'kmaw Conservation Group: Black Ash and Native Tree Education and Restoration. Mi'kmaq Maliseet Nations News, Truro, NS. Web site: http://www.mmnn.ca/2013/09/mcg-the-black-ash-project/ [accessed January 2017]

Kartesz, J.T. 2015. *Fraxinus nigra*, North American Plant Atlas. Maps generated from Kartesz, J.T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP). (in press). Web site: http://bonap.net/napa [accessed April 2016].

Kashian, D.M., 2016. Sprouting and seed production may promote persistence of green ash in the presence of the emerald ash borer. Ecosphere 7 (4), e01332. Web site: http://dx.doi.org/10.1002/ecs2.1332.

Kashian, D.M., L.S. Bauer, B.A. Spei, J.J. Duan, and J.R. Gould. 2018. Potential impacts of Emerald Ash Borer biocontrol on ash health and recovery in southern Michigan. Forests. 9(6):296

Kashian, D.M., and J.A. Witter. 2011. Assessing the potential for ash canopy tree replacement via current regeneration following emerald ash borer-caused mortality on southeastern Michigan landscapes. For. Ecol. Manage. 261, 480– 488. Web site: http://dx.doi.org/10.1016/j.foreco.2010.10.033.

Kaur, R., C. Knott, and M.C. Aime. 2010. First report of Rust Disease caused by *Puccinia sparganioides* on *Spartina alterniflora* in Louisiana. Plant Disease. 94(5):636.

Kershner, J. 2015. Restoration and Conservation of Black Ash Trees in the Northern Appalachian/Acadian Eco-region of Canada [by the Mi'kmaq Confederacy of Prince Edward Island]. Climate Adaptation Knowledge Network. Web site: http://www.cakex.org/case-studies/restoration-and-conservation-black-ash-trees-northern-appalachianacadian-eco-region [accessed January 2017]

Kirkpatrick, B.C. 1997. Phytoplasmas: the evolution of a molecular taxonomic genus. Nachrichtenblatt des Deutschen Pflanzenschutzdienstes. 49(5):126-130.

Klooster, W.S., D.A. Herms, K.S. Knight, C.P. Herms, D.G. McCullough, A. Smith, K.J.K. Gandhi, and J. Cardina. 2014. Ash (*Fraxinus* spp.) mortality, regeneration, and seed bank dynamics in mixed hardwood forests following invasion by emerald ash borer (*Agrilus planipennis*). Biological Invasions. 16:859-873.

Klooster, W.S., K.J.K. Gandhi, L.C. Long, K.I. Perry, K.B. Rice, and D.A. Herms. 2018. Ecological impacts of Emerald Ash Borer in forests at the epicenter of the invasion in North America. Forests. 9(5):250.

Knight, K.S., R.P. Long, J. Rebbeck, A. Smith, K. Gandhi, and D.A. Herms. 2007. How fast will trees die? A transition matrix model of ash decline in forest stands infested by emerald ash borer. In: Mastro, V., D. Lance, R. Reardon and G. Parra (Eds.). Emerald Ash Borer Research and Technology Development Meeting. Forest Health Technology Enterprise Team, Morgantown WV. Pittsburgh PE. October 23-24, 2007. p. 28.

Knight, K., J. Brown, and R. Long. 2013. Factors affecting the survival of ash (*Fraxinus* spp.) trees infested by emerald ash borer (*Agrilus planipennis*). Biological Invasions. 15:371-383.

Knight K.S., D.A. Herms, R. Plumb, E. Sawyer, and D. Spalink. 2012. Dynamics of surviving ash (*Fraxinus* spp.) populations in areas long infested by Emerald Ash Borer (*Agrilus planipennis*). In: Sniezko, R.A., A.D. Yanchuk, J.T. Kliejunas, K.M. Palmieri, J.M. Alexander and S.J. Frankel (Eds.). Proceedings of the Fourth International Workshop on Genetics of Host-Parasite Interactions. Albany CA. General Technical Report PSW-GTR-240. pp. 143-152.

Knight, K.S., R.A. Ford, D.A. Herms, C.E. Flower, K.J. Gandhi, D. Hartzler, B.M. Hoven, W.K. Bethel, R.P. Long, and A. Smith. 2014. Ash decline and mortality, tree fall, and emerald ash borer population dynamics at forest stand and landscape scales 2004-2014. In: Buck, J., G. Parra, D. Lance, R. Reardon and D. Binion (Eds.). 2014 Emerald Ash Borer National Research and Technology Development Meeting. Ohio Agricultural Research and Development Center, Wooster OH. October 15-16, 2014. p. 35.

Koch, J., D. Carey, K. Knight, T. Poland, D. Herms, and M. Mason. 2012. Breeding strategies for the development of emerald ash borer resistant—North American ash. In: Sniezko, R.A., A.D. Yanchuk, J.T. Kliejunas, K.M. Palmieri, J.M. Alexander and S.J. Frankel (Eds.). Proceedings of the 4th International Workshop on Genetics of Host-Parasite Interactions. Albany CA. General Technical Report PSW-GTR-240. pp. 235-239.

Koop, A.L. 2005. *Psyllopsis discrepans* Flor: cottony psyllid. NPAG Report. USDA-APHIS, PPQ New Pest Advisory Group.

Kornelson, J., and C. Hamel. 2015. Observations of high quality eastern deciduous riparian sites in southeast Manitoba's Whitemouth River Watershed. Blue Jay 73: 168-182.

Kopra, K. 2006. Forestry without herbicides: the Quebec experience. Presentation at Northwatch’s 2006 Symposium on Herbicide use in Forest Management, June 16th 2006, Timmins ON.

Kovacs, K.F., R.G. Haight, D.G. McCullough, R.J. Mercader, N.W. Siegert, and A.M. Liebhold. 2010. Cost of potential emerald ash borer damage in US communities, 2009–2019. Ecological Economics. 69(3):569-578.

Kowalski T. 2006. *Chalara fraxinea* sp. nov. associated with dieback of ash (*Fraxinus Excelsior*) in Poland. Forest Pathology. 36:264-70.

Kowalski, T., and O. Holdenrieder. 2009. Pathogenicity of *Chalara fraxinea*. Forest Pathology. 39(1):1-7.

Kudish, M. 1992. Adirondack upland flora: an ecological perspective. The Chauncy Press. Saranac, NY. 320 pp.

Kurmis, V, S.L. Webb, and L.C. Merriam (Jr.). 1986. Plant communities of Voyageurs National Park, Minnesota, U.S.A. Canadian Journal of Botany. 64:531-540.

Kurmis, V., and J.H. Kim. 1989. Black Ash stand composition and structure in Carlton County, Minnesota. Department of Forest Resources Staff Paper Series, no. 69. University of Minnesota, Twin Cities.

Labrecque, J., pers. comm. 2017. Email correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash in Quebec and Ontario. Botanist, Ministère du développement durable, de l’environnement et de la lutte contre les changements climatiques, Quebec QC.

Lavallée, R. pers. comm. 2018. June 2018. Email correspondence with C.S. Blaney, concerning the effects of Emerald Ash Borer on Black Ash in Ontario. Research Scientist, Laurentian Forestry Centre, Québec QC,

Lee, P.G., M. Hanneman, and R. Cheng. 2012. Hydropower Developments in Canada: Number, Size and Jurisdictional and Ecological Distribution. Global ForestWatch Canada, 2012, Year of Sustainable Energy for All #2. Edmonton AB. 64 pp. Web site: http://globalforestwatch.ca/sites/gfwc/files/publications/20120118A_Hydro1_Number_Size_Distribution.pdf [accessed January 2017]

Lees, J.C.W., and R.C. West. 1988. A Strategy for Growing Black Ash in the Maritime Provinces. Canadian Forestry Service, Maritime Forest Research Centre, Fredericton, N.B., Forest Technical Note 201.

Lenhart, C., K. Brooks, M. Davidson, R. Slesak, and A. D'Amato. 2012. Hydrologic source characterization of Black Ash wetlands: implications for EAB response. In: Proceedings of the American Water Resource Association Summer Specialty Conference. Riparian Ecosystems IV: Advancing Science, Economics and Policy, Denver CO, June 27-29.

Levy, G.F. 1970. The phytosociology of northern Wisconsin upland openings. American Midland Naturalist. 83:213-237.

Levy, S. 2006. A plague of deer. BioScience. 56(9):718-721.

Lichvar, R.W., D.L. Banks, W.N. Kirchner, and N.C. Melvin. 2016. The National Wetland Plant List: 2016 wetland ratings. Phytoneuron 2016-30: 1-17. Published 28 April 2016. ISSN 2153 733X Web Site: http://rsgisias.crrel.usace.army.mil/NWPL/

Livingston, W.H., and A.S. White. 1997. May drought confirmed as likely cause of brown ash dieback in Maine. Phytopathology. 87:S59.

Littlefield, T.R. pers. comm. 2016. November 2016. Email correspondence with C.S. Blaney, concerning the status of Black Ash in Kentucky. Rare Plant Botanist, Kentucky State Nature Preserves Commission, Frankfort KY.

Liu, H.P., L.S. Bauer, R. Gao, T. Zhao, T.R. Petrice, and R.A. Haack. 2003. Exploratory survey for the emerald ash borer, *Agrilus planipennis* (Coleoptera:Buprestidae), and its natural enemies in China. Great Lakes Entomologist. 36:191-204.

Loo, J., and N. Ives. 2003. The Acadian forest: historical condition and human impacts. The Forestry Chronicle. 79:462-474.

Lyons, B.D., G.C. Jones, and K. Wainio-Keizer. 2003. The biology and phenology of the Emerald Ash Borer, *Agrilus planipennis*. In: Mastro, V., Reardon, R. (Eds.). Abstracts of Emerald Ash Borer Research and Technology Development Meeting. Forest Health Technology Enterprise Team, Morgantown WV. USDA FHTET-2004-02.

MacDougall, A. 2003. Did Native Americans influence the northward migration of plants during the Holocene?. Journal of Biogeography. 30:633–647. DOI: 10.1046/j.1365-2699.2003.00842.x

MacFarlane, D.W., and S.P. Meyer. 2005. Characteristics and distribution of potential ash tree hosts for emerald ash borer. Forest Ecology and Management. 213(1):15-24.

McGarrigle, E. pers. comm. 2017. February 2017. Email correspondence with C.S. Blaney and D.M. Mazerolle, concerning forest inventory data in Nova Scotia. Data Analyst, Nova Scotia Department of Natural Resources, Truro NS.

Machado-Caballero, J.E., B.E. Lockhart, S.L. Mason, D. Mollov, and J.A. Smith. 2013. Identification, transmission, and partial characterization of a previously undescribed flexivirus causing a mosaic disease of ash (*Fraxinus* spp.) in the USA. Plant Health Progress. Web site: http://sfrc.ufl.edu/forestpathology/wp-content/uploads/2013/12/Machado-Caballero-et-al-2013.pdf [accessed May 2016]

MacPhail, M. pers. comm. 2007. March 2007. Discussion between Mark MacPhail and Donna Hurlburt concerning sourcing ash for basketry in Nova Scotia. Director of Forestry, Unama'ki Institute of Natural Resources, Eskasoni, NS.

MapBioControl. 2013. Emerald Ash Borer Biological Control Program: Number of Release Sites per County. Online map. Web site: http://maps.asets.msu.edu/carball1@msu.edu/mb2_release_sites_by_county_usa.pdf [accessed May 2017]

Marie-Victorin, frère, 1935. Flore Laurentienne. Imprimerie de La Salle, Montréal. [1995: 3rd edition updated by L. Brouillet, S. Hay and I. Goulet with contributions from J. Cayouette, M. Blondeau and J. Labrecque.] Les presses de l'Université de Montréal, Montréal. 1093 pp.

Martin, A.C., H.S. Zim and A.L. Nelson. 1951. American Wildlife and Plants: A Guide to Wildlife Food Habits. Dover Publications NY. 512 pp.

Mason, P. undated. Psyllid Attack on North Dakota Black Ash Resource. US Department of Agriculture, Animal and Plant Health Inspection Service. North Dakota and Montana. PDF file from slide presentation. Web site: https://www.ag.ndsu.edu/pdl/documents/Psyllid_ND.pdf [accessed February 2017]

Matsuoka, S.M., C.M. Handel, and D.R. Ruthrauff. 2001. Densities of breeding birds and changes in vegetation in an Alaskan boreal forest following a massive disturbance by spruce beetles. Canadian Journal of Zoology. 79:1678-1690.

Maw, H.E.L., R.G. Foottit, K.G.A. Hamilton, and G.G.E. Scudder. 2000. Checklist of the Hemiptera of Canada and Alaska. National Research Council Research Press. Ottawa ON. 220 pp.

McCaul, E. pers. comm. 2017. Correspondence with C.S. Blaney, concerning the presence of Black Ash in Ontario Parks. Ecologist, Northwest Science and Information, Ontario Ministry of Natural Resources and Forestry, Thunder Bay ON.

McCullough, D.G., and S.A. Katovich. 2004. Pest alert: emerald ash borer. United States Forest Service, Northeastern Area. NA-PR-02-04.

McCullough, D.G., and N.W. Siegert. 2007. Estimating potential emerald ash borer (Coleoptera: Buprestidae) populations using ash inventory data. Journal of Economic Entomology. 100(5):1577-1586.

McCullough D.G., N.F. Schneeberger, and S.A. Katovich. 2008. Emerald ash borer pest alert. NA-PR-02-04. USDA Forest Service.

McCullough, D.G., S.R. Tanis, M. Robinett, C. Limback, and T.M. Poland. 2014. White ash – is EAB always a death sentence?. In: Buck, J., G. Parra, D. Lance, R. Reardon and D. Binion (Eds.). 2014 Emerald Ash Borer National Research and Technology Development Meeting. Ohio Agricultural Research and Development Center, Wooster OH. October 15-56, 2014. p. 10.

MCDC (Manitoba Conservation Data Centre). 2016. Black Ash occurrence data. Manitoba Department of Sustainable Development. [received from Chris Friesen, MCDC Coordinator, in May 2016]

McKenney, D.W., J.H. Pedlar, K. Lawrence, P. Papadopol, K. Campbell, M.F. Hutchinson, R.E. Kramers, and N. Morisset. 2014. Extreme minimum temperature zones. Natural Resources Canada.

McKinney, M.L., R. Schoch, and L. Yonavjak. 2013. Environmental Science: Systems and Solutions, 5th Ed. Jones & Bartlett Learning, Burlington MA. 693 pp.

McLaren, B., C. McCarthy, and S. Mahoney. 2000. Extreme moose demographics in Gros Morne National Park, Newfoundland. Alces. Winter 2000:217-233.

McLaren, B.E., B.A. Roberts, N. Djan-Chekar, and K.P. Lewis. 2004. Effects of verabundant moose on the Newfoundland landscape. Alces. 40:45-59.

Meeker, J.E., I.E. Elias, and J.A. Heim. 1993. *Plants Used by the Great Lakes Ojibwa.* Great Lakes Indian Fish and Wildlife Commission, Odanah, WI.

Mercier, J. pers. comm. 2016. May 2016. Email and telephone correspondence with D.M. Mazerolle, concerning the distribution, abundance and standing timber volume of Black Ash in Quebec. Forestry Technician, Direction des inventaires forestiers, Ministère des Forêts, de la Faune et des Parcs du Québec, Quebec QC.

MFFPQ (Ministère des forêts, de la faune et des parcs du Québec). 2015. État de la forêt publique du Québec et de son aménagement durable – Bilan 2008-2013. Bureau du forestier en chef, Gouvernement du Québec, Roberval QC. 382 pp.

MFFPQ (Ministère des forêts, de la faune et des parcs du Québec). 2016. Forest inventory sampling plot data. [received from Jean Mercier, Forestry Technician, in May 2016]

MFFPQ (Ministère des Forêts, de la Faune et des Parcs Québec). 2018. Résultats d’inventaire et carte écoforestière. Web site: https://www.donneesquebec.ca/recherche/fr/dataset/resultats-d-inventaire-et-carte-ecoforestiere [Accessed March 2018]

Mi’kmaq Confederacy of Prince Edward Island. 2014. Geographic Information Systems –The Journey of the Black Ash Project. MCPEI, Charlottetown, PE. Web site: http://www.mcpei.ca/node/53 [accessed January 2014]

Minnesota DNR (Department of Natural Resources). 2007. Minnesota Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife. Minnesota's Comprehensive Wildlife Conservation Strategy. Minnesota Department of Natural Resources. Web site: http://files.dnr.state.mn.us/assistance/nrplanning/bigpicture/cwcs/habitats/07.pdf [accessed January 2017]

Montigny, M.K., and D.A. MacLean. 2005. Using heterogeneity and representation of ecosite criteria to select forest reserves in an intensively managed industrial forest. Biol. Conserv. 125: 237–248.

Moore, J.E., A.B. McEuen, R.K. Swihart, T.A. Contreras, and M.A. Steele. 2007. Determinants of seed removal distance by scatter-hoarding rodents in deciduous forests. Ecology. 88:2529–2540.

Morin, X., C. Augspurger, and I. Chuine. 2007. Process-based modeling of species' distributions: what limits temperate tree species' range boundaries?. Ecology. 88(9):2280-2291.

Morin, X., D. Viner, and I. Chuine. 2008. Tree species range shifts at a continental scale: new predictive insights from a process-based model. Journal of Ecology. 96(4):784-794.

Muirhead, J.R., B. Leung, C. Overdijk, D.W. Kelly, K. Nandakumar, K.R. Marchant, and H.J. MacIsaac. 2006. Modelling local and long-distance dispersal of invasive emerald ash borer *Agrilus planipennis* (Coleoptera) in North America. Diversity and Distributions. 12(1):71-79.

Nair, V.M.G., C.J. Kostichka, and J.E. Kuntz. 1979. *Sirococcus clavigignenti-juglandacearum*: an undescribed species causing canker on butternut. Mycologia. 71:641-645.

Nantel, P. pers. comm. 2018. February 2017 (additional information provided February 2018). Email correspondence with C.S. Blaney, concerning the presence of Black Ash in national parks and national historic sites. Ecosystem Scientist, Parks Canada, Gatineau QC.

NCBI (National Centre for Biotechnology Information). 2017. Sequence Analysis Databases. Web site: https://www.ncbi.nlm.nih.gov/guide/sequence-analysis/ [accessed January 2017]

National Forest Inventory. 2013. Revised baseline 2006 data from Canada's National Forest Inventory. Version 3, December 2013. National Resources Canada, Canadian Forest Service. Web site: http://nfi.nfis.org [accessed January 2017]

Natural Resources Canada. 2013. The State of Canada's Forests: Annual Report 2013. Natural Resources Canada, Canadian Forest Service. 62 pp. Web site: http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/35191.pdf [accessed December 2016]

Natural Resources Canada. 2014. The State of Canada's Forests: Annual Report 2014. Natural Resources Canada, Canadian Forest Service. 72 pp. Web site: http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/35713.pdf [accessed December 2016]

Natural Resources Canada. 2015. The State of Canada's Forests: Annual Report 2015. Natural Resources Canada, Canadian Forest Service. 76 pp. Web site: http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/36553.pdf [accessed December 2016]

NatureServe. 2017. NatureServe Explorer - *Fraxinus nigra*. Web site: http://explorer.natureserve.org/servlet/NatureServe?searchName=Fraxinus+nigra [accessed January 2017]

NBDERD (New Brunswick Department of Energy and Resource Development). 2016. Forest Development Survey plot data, permanent sample plot data and staff personal observations. [received from Mary Sabine, Species at Risk Biologist, in May 2016]

NBM (New Brunswick Museum). 2016. Specimen database. [received from Stephen Clayden, herbarium curator, in May 2016]

NLDEC (Newfoundland and Labrador Department of Environment and Conservation). 2015. 2015-2010 Newfoundland and Labrador Moose Management Plan. St. John's NL. 25 pp. Web site: http://www.ecc.gov.nl.ca/moose_plan.pdf [accessed January 2017]

Norberg, R.A. 1973. Autorotation, self-stability, and structure of single-winged fruits and seeds (samaras) with comparative remarks on animal flight. Biological Reviews. 48:561-596. DOI: 10.1111/j.1469-185X.1973.tb01569.x

Nova Scotia Legislature. 2017. Bill No. 65 (as amended), Endangered Species Act: Chapter 11 of the Acts of 1998. Web site: http://nslegislature.ca/legc/bills/57th_1st/3rd_read/b065.htm [accessed January 2017]

NS DNR (Nova Scotia Department of Natural Resources). 2017. Permanent sample plot data, for plots containing Black Ash (1965-present), and for current age classes of all plots (2013-2016). Unpublished data, Nova Scotia Department of Natural Resources, Forestry Division, Truro, NS.

NTSC (National Tree Seed Centre). 2016. Seed lot germination potential and viability test results. [received from Dale Simpson, Manager, National Tree Seed Centre, in May 2016]

Oldham, M.J. pers. comm. 2017. January and February 2017. Email and telephone correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash in Ontario and Quebec. Botanist, Ontario Natural Heritage Information Centre, Ministry of Natural Resources and Forestry, Peterborough ON.

OFRI (Ontario Forest Research Institute). 2017. Ontario Forest Research Institute survey plot data. Ontario Ministry of Natural Resources and Forestry. Sault Ste. Marie ON. [received from Monique Wester, Ecologist, Ontario Forest Research Institute, in February 2017]

OMNR (Ontario Ministry of Natural Resources). 2005. Forest conservation by-laws in Ontario. Ontario Ministry of Natural Resources Extension Notes. OMNR Landowner Resource Centre, Manotick ON. Web site: http://www.forestsontario.ca/wp-content/uploads/2016/01/conservation_bylaw.pdf [accessed January 2017]

OMNR (Ontario Ministry of Natural Resources). 2007. State of Ontario's Forests. Queen's Printer for Ontario, Toronto ON.

OMNR (Ontario Ministry of Natural Resources). 2010. Forest Health Alert: Emerald Ash Borer. Web site: http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_166994.html [accessed December 2010]

OMNR (Ontario Ministry of Natural Resources). 2011. The Forest Resources of Ontario 2011. Ontario Ministry of Natural Resources, Forest Evaluation and Standards Section, Forests Branch. Sault Ste. Marie ON. 307 pp.

OMNRF (Ontario Ministry of Natural Resources and Forestry). 2016a. Forest resources inventory data. Ontario Ministry of Natural Resources and Forestry, Peterborough ON. [received from Shari MacDonald, Metadata Administrator, Land Information Ontario, in May 2016].

OMNRF (Ontario Ministry of Natural Resources and Forestry). 2016b (draft). The Forest Resources of Ontario 2016. Ontario Ministry of Natural Resources and Forestry, Forest Sustainability and Information Section. Sault Ste. Marie ON. Queen's Printer for Ontario, Toronto ON. 98 pp.

ONHIC (Ontario Natural Heritage Information Centre). 2016. Black Ash occurrence data and staff personal observations. Ontario Ministry of Natural Resources and Forestry, Peterborough ON. [received from Tanya Taylor and Michael J. Oldham, ONHIC, in May 2016 and January 2017]

OPIAM (Ontario Parks Inventory and Monitoring Program). 2017. Ontario Parks Inventory and Monitoring Program survey plot data. Ontario Ministry of Natural Resources and Forestry, Thunder Bay ON. [received from Evan McCaul, Ecologist, Northwest Science and Information, in February 2017]

Ormes, M. pers. comm. 2017. February 2017. Email correspondence with D.M. Mazerolle, concerning subnational status ranks and ranking dates for Black Ash in the United States. Director of Science Information Resources, NatureServe, University of Massachusetts, Boston MA.

Ossiannilsson, F., 1992. The Psylloidea (Homoptera) of Fennoscandia and Denmark (Vol. 26). Brill.

Palik, B.J., M.E. Ostry, R.C. Venette, and K.T. Ward. 2008. Assessment of Black Ash (*Fraxinus nigra*) Decline in Minnesota. In: Potter, K.M. and B.L. Conkling (eds.). Forest Health Monitoring: 2008 National Technical Report. General Technical Report SRS-158. US Department of Agriculture, Forest Service, Southern Research Station. pp. 151-154.

Palik, B.J., M.E. Ostry, R.C. Venette, and E. Abdela. 2011. *Fraxinus nigra* (Black Ash) dieback in Minnesota: regional variation and potential contributing factors. Forest Ecology and Management. 261(1):128-135.

Palik, B.J., M.E. Ostry, R.C. Venette, and E. Abdela. 2012. Tree regeneration in Black Ash (*Fraxinus nigra*) stands exhibiting crown dieback in Minnesota. Forest Ecology and Management. 269:26-30.

Pautasso, M., G. Aas, V. Queloz, and O. Holdenrieder. 2013. European ash (*Fraxinus excelsior*) dieback - a conservation biology challenge. Biological Conservation. 158:37-49.

Pellerin, S. pers. comm. 2017. February 2017. Email correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash on Anticosti Island, QC. Adjunct Professor, Université de Montréal, Montreal QC.

Percy, D.M. 2014. Psyllids or 'jumping plant lice' (Psylloidea, Hemiptera). Psyllids of Economic Importance. Web site: http://www.psyllids.org/psyllidsPests.htm [accessed February 2017]

Peterson, C.E., 1989. Natural regeneration after logging of Black Ash stands in central Minnesota. Master's thesis. College of Natural Resources, University of Minnesota, St.Paul MN. 58 pp.

Phytoplasma Resource Center. 2017. Molecular Plant Pathology Laboratory, US Department of Agriculture - Agricultural Research Service. Beltsville, MD. Web site: http://plantpathology.ba.ars.usda.gov/pclass/pclass_phytoplasmaclassification_system2.html [accessed January 2017].

Pimlott, D.H. 1959. Reproduction and productivity of Newfoundland moose. The Journal of Wildlife Management. 23(4):381-401.

Pokorny, J.D., and W.A. Sinclair. 1994. How to identify and manage ash yellows in forest stands and home landscapes. Northeastern Area State and Private Forestry. USDA Forest Service. 6 p.

Poland, T.M., and D.G. McCullough. 2006. Emerald ash borer: Invasion of the urban forest and the threat to North American's ash resource. Journal of Forestry. 104:118-124.

Pomerleau, R. 1944. Observations sur quelques maladies non-parasitaires des arbres dans le Québec. Canadian Journal of Research. 22c:171-189.

Potvin, F., P. Beaupré, and G. Laprise. 2003. The eradication of balsam fir stands by white-tailed deer on Anticosti Island, Québec: a 150-year process. Ecoscience. 10(4):487-495.

Potvin, F., and L. Breton. 2005. Testing two aerial survey techniques on deer in fenced enclosures: visual double-counts and thermal infrared sensing. Wildlife Society Bulletin. 33(1):317-325.

Powell, G., and T. Beardmore. 2007. New Brunswick Tree and Shrub Species of Concern - A Field Guide. Canadian Forest Service - Atlantic Forestry Centre, Fredericton, NB.

Prasad, A.M., L.R. Iverson, M.P. Peters, J.M. Bossenbroek, S.N. Matthews, T.D. Sydnor, and M.W. Schwartz. 2010. Modeling the invasive emerald ash borer risk of spread using a spatially explicit cellular model. Landscape Ecology. 25:353-369.

Quebec Legislature. 2017. Bill No. Q2 R35: Politique de protection des rives, du littoral et des plaines inondables (last amended in 2014). Web site: http://legisquebec.gouv.qc.ca/fr/ShowDoc/cr/Q-2,%20r.%2035/ [accessed February 2017]

Queloz, V., C.R. Grunig, R. Berndt, T. Kowalski, T.N. Sieber, and O. Holdenrieder. 2011. Cryptic speciation in *Hymenoscyphus albidus*. Forest Pathology. 41:133-142.

Rebek, E.J., D.A. Herms, and D.R. Smitley. 2008. Interspecific variation in resistance to emerald ash borer (Coleoptera:Buprestidae) among North American and Asian ash (*Fraxinus* spp.). Environmental Entomology. 37:242-246.

Redfern, M., and P. Shirley. 2002. British Plant Galls. Identification of Galls on Plants and Fungi. Shrewsbury: FSC Publications. ISBN 1-85153-214-5.

Reiners, W.A., and N.M. Reiners. 1970. Energy and nutrient dynamics of forest floors in three Minnesota forests. Journal of Ecology. 58:497-579.

Reznicek, A.A. 2016. November 11, 2016. Email correspondence with C.S. Blaney, regarding range of Black Ash in Michigan and surrounding states. Curator (Vascular Plants); Research Scientist, University of Michigan Research Museums Center, Ann Arbor, MI.

Roberts, W. 2005. Integrating Traditional Ecological Knowledge and Ecological Restoration: Restoring Aboriginal Cultural Landscapes with Iskatewizaagegan No. 39 Independent First Nation. Master's of Natural Resource Management thesis, University of Manitoba, Winnipeg, Manitoba. 189 pp. Web site: http://umanitoba.ca/institutes/natural_resources/canadaresearchchair/thesis/wroberts%20masters%20thesis%202005.pdf [accessed January 2014].

Ronald, W.G. 1972. Range extension of Black Ash, *Fraxinus nigra* Marsh., in Manitoba. The Canadian Field-Naturalist. 86(1):73-74.

Ronald, W.G. 1976. Fallgold Black Ash. Canadian Journal of Plant Sciences. 56:405.

Rousseau, J. 1947. Ethnobotanique Abenakise. Archives de Folklore. 11:145-182.

Rousseau, C. 1974. Géographie floristique du Québec Labrador. Distribution des principales espèces vasculaires. Québec: Les Presses de l'Université Laval, Québec QC. 798 pp.

Rowlinson, D. 2017. Forest Health Program: Then and Now. Presentation to: Boreal Forest Health Information Session, Forestry Futures Trust Ontario, Thunder Bay, ON. March 22 2017. Ontario Ministry of Natural Resources and Forestry, Provincial Forest Health Program Coordinator, Sault Ste. Marie, ON. Web site: http://www.forestryfutures.ca/Forest%20Health%20-Then%20and%20Now.pdf [Accessed May 2017].

Rowlinson, D. pers. comm. 2017. March 2017. Telephone correspondence with C.S. Blaney, concerning the effects of Emerald Ash Borer on Black Ash in Ontario. Forest Health Field Coordinator, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie ON.

Roy, V., J.-C. Ruel, and A.P. Plamondon. 2000. Establishment, growth and survival of natural regeneration after clearcutting and drainage on forested wetlands. Forest Ecology and Management. 129(1):253-267.

Runesson, U.T. 2017. Common Tree Species of the Boreal Forest – Black Ash. Borealforest.org, Lakehead University, Thunder Bay ON. Web site: https://www.borealforest.org/trees/tree4.htm [accessed January 2017]

Ryall, K. 2017. Release of exotic parasitoids for the biological control of emerald ash borer in Canada: Progress Report. Great Lakes Forestry Research Centre, Canadian Forest Service, Sault Ste. Marie ON. 13 pp.

Sabine, M. pers. comm. 2017. August 22, 2017. Email communication by Mary Sabine to Neil Jones (COSEWIC Scientific Project Officer & Aboriginal Traditional Knowledge Coordinator), provided to Sean Blaney. Species at Risk Biologist, New Brunswick Department of Energy and Resource Development, Fredericton NB.

Sakai, A., and W. Larcher. 1987. Frost survival of plants. Springer-Verlag, Berlin, Germany.

Santamour, F.S. (Jr.), and A.J. McArdle. 1983. Checklist of Cultivars of North American Ash (*Fraxinus*) Species. Journal of Arboriculture. 9:271-276.

Schopmeyer, C.S. (ed). 1974. Seeds of woody plants in the United States. US Department of Agriculture, Agriculture Handbook 450. Washington, DC. 883 pp.

Schmiedel, D., and O. Tackenberg. 2013. Hydrochory and water induced germination enhance invasion of *Fraxinus pennsylvanica.* Forest Ecology and Management. *304:437-443. Web site:* http://dx.doi.org/10.1016/j.foreco.2013.04.027

Schmitt, J. 1904. Monographie de l'île d'Anticosti (Golfe Saint-Laurent). Hermann, Paris. 370 pp. Web site: https://archive.org/details/monographiedell00schmgoog [accessed December 2016]

Siegert, N.W., D.G. McCullough, A.M. Liebhold, and F. Telewski. 2007. Resurrected from the ashes: a historical reconstruction of emerald ash borer dynamics through dendrochronological analyses. In: Mastro, V., R. Reardon, and G. Parra (Eds.). Proceedings of the Emerald Ash Borer Research and Technology Development Meeting. Cincinnati, Ohio. U.S. October 31 to November 1. Forest Service publication FHTET 2007–04. pp. 18-19.

Siegert, N.W., A.R. Tluczek, and D.G. McCullough. 2014. Susceptibility of selected Asian, European, and North American ash species to Emerald ash borer: preliminary results of no-choice bioassays. In: Buck, J., G. Parra, D. Lance, R. Reardon and D. Binion (Eds.). 2014 Emerald Ash Borer National Research and Technology Development Meeting. Ohio Agricultural Research and Development Center, Wooster OH. October 15-16, 2014. p. 84.

Simpson, J.D. pers. comm. 2016. May 2016. Email correspondence with D.M. Mazerolle, concerning Black Ash seed viability, germination potential and germination requirements. Manager, National Tree Seed Centre, Canadian Forest Service, Fredericton NB**.**

Simpson, J.D., J.A. Loo, and D.A. McPhee. 2008. Genetic Variation of Black Ash in Nova Scotia. Natural Resources Canada Canadian Forest Service – Atlantic Forestry Centre, Fredericton, NB and the Confederacy of Mainland Mi'kmaq, Millbrook, NS. 10 pp.

Sims, R.A., H.M. Kershaw, and G.M. Wickware. 1990. The autecology of major tree species in the north central region of Ontario. COFRDA (Canada-Ontario Forest Resources Development Agreement) Report 3302. Northwestern Ontario Forest Technology Development Unit. Technical Report 48. Forestry Canada, Ontario Region, Ottawas. Ontario Ministry of Natural Resources, Thunder Bay ON. 126 pp.

Sinclair, W.A., H.M. Griffiths, and I.M. Lee. 1994. Mycoplasma-like organisms as causes of slow growth and decline of trees and shrubs. Journal of Arboriculture. 20:176-176.

Sinclair, W.A., H.M. Griffiths, and R.E. Davis. 1996. Ash yellows and lilac witches'-broom: phytoplasmal diseases of concern in forestry and horticulture. Plant Disease. 80(5):468-475.

Skilling, D.D. 1964. Part 5. Ecological factors associated with maple blight. In: Studies of Maple Blight. University of Wisconsin Agricultural Experiment Station Research Bulletin. 250:114-129.

Slesak, R.A., C.F. Lenhart, K.N. Brooks, A.W. D'Amato, and B.J. Palik. 2014. Water table response to harvesting and simulated emerald ash borer mortality in Black Ash wetlands in Minnesota, USA. Canadian Journal of Forest Research. 44(8): 961-968.

Smith, H.H. 1923. Ethnobotany of the Menomini Indians. Bulletin of the Public Museum of Milwaukee. 4:1-174.

Smith, H.H. 1928. Ethnobotany of the Meskwaki Indians. Bulletin of the Public Museum of Milwaukee. 4:175-326.

Smith, H.H. 1932. Ethnobotany of the Ojibwe Indians. Bulletin of the Public Museum of Milwaukee. 4:327-525.

Smith, G., and J.E. Hurley. 2000. First North American record of the palearctic species *Tetropium fuscum* (Fabricius) (Coleoptera: Cerambycidae). The Coleopterists Bulletin. 54:540.

Smith, T.D., C. Smith, and S.M. Hill. 2000. Germination of excised Black Ash, *Fraxinus nigra* Marshall (Oleaceae), embryos in growth media. Report presented to Nova Forest Alliance, Nova Scotia. Available from Nova Forest Alliance, Stewiacke, Nova Scotia.

Smith, A., D.A. Herms, and R.P. Long. 2005. The impact of Emerald Ash Borer on forests within the Huron River watershed. In: Mastro, V.C., R. Reardon and G. Parra (Eds.). Emerald Ash Borer Research and Technology Development Meeting. Forest Health Technology Enterprise Team, Morgantown WV. Pittsburgh PE. September 26-27, 2005. p. 22.

Smith, C., K. Beazley, P. Duinker, and K.A. Harper. 2010. The impact of Moose (*Alces alces andersoni*) on forest regeneration following a severe spruce budworm outbreak in the Cape Breton Highlands, Nova Scotia, Canada. Alces. 46:135-150.

Sobek-Swant, S., J.C. Crosthwaite, D.B. Lyons, and B. J.Sinclair. 2012. Could phenotypic plasticity limit an invasive species? Incomplete reversibility of mid-winter deacclimation in emerald ash borer. Biological Invasions 14:115-125.

Sork, V., and P. Smouse. 2006. Genetic analysis of landscape connectivity in tree populations. Landscape Ecology. 21:821-836.

Speck, F.G., and R.W. Dexter (1951). Utilization of animals and plants by the Micmac Indians of New Brunswick. Journal of the Washington Academy of Sciences. 40(8):250-259.

Speck, F.G., and R.W. Dexter (1952). Utilization of animals and plants by the Malecite Indians of New Brunswick. Journal of the Washington Academy of Sciences. 42(1):1-7.

Statistics Canada. 2017a. Censuses of Canada 1665 to 1871: The 1800s (1806 to 1871). Web site: http://www.statcan.gc.ca/pub/98-187-x/4064809-eng.htm [accessed January 2017]

Statistics Canada. 2017b. Rural and Urban Population Changes for Ontario since 1851. Web site: http://www40.statcan.ca/l01/cst01/demo62g.htm [accessed January 2017]

Steinbauer, G.P. 1937. Dormancy and germination of *Fraxinus* seeds. Plant Physiology. 12:813-824.

Stewart, H.A., and J.E. Krajicek. 1978. Ash: an American wood. USDA Forest Service, North Central Forest Experiment Station. Technical Report FS-216. 8 pp.

Stoney Point First Nation. 2006. Aazhoodena The History of Stoney Point First Nation. Project of the Aazhoodena and George Family Group for the Ipperwash Inquiry. 45 pp. Web site: http://www.attorneygeneral.jus.gov.on.ca/inquiries/ipperwash/policy_part/projects/pdf/Aazhoodena_history.stoney.point.pdf [accessed January 2015].

Straw, N.A., D.T. Williams, O. Kulinich, and Y.I. Gninenko. 2013. Distribution, impact and rate of spread of emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) in the Moscow region of Russia. Forestry 86: 515–522, doi:10.1093/forestry/cpt031

Sturrock, R.N., S.J. Frankel, A.V. Brown, P.E. Hennon, J.T. Kliejunas, and K.J. Lewis. 2011. Climate change and forest diseases. Plant Pathology. 60:133-149.

Sun, S.S. 1985. Studies on the genus *Fraxinus* L. (Oleaceae) in China. Bulletin of Botanical Research. 5:37-67.

Sutherland, E.K., B.J. Hale, and D.M. Hix. 2000. Defining species guilds in the central hardwood forest, USA. Plant Ecology. 147: 1-19.

Tanis, S.R., and D.G. McCullough. 2015. Host resistance of five *Fraxinus* species to *Agrilus planipennis* (Coleoptera: Buprestidae) and effects of paclobutrazol and fertilization. Environmental Entomology. 44(2):287-299.

Tardif, J., and Y. Bergeron. 1992. Analyse écologique des peuplements de frêne noir (*Fraxinus nigra*) des rives du lac Duparquet, nord-ouest du Québec. Canadian Journal of Botany. 70:2294-2302.

Tardif, J., and Y. Bergeron. 1993. Radial growth of *Fraxinus nigra* in a Canadian boreal floodplain in response to climatic and hydrological fluctuations. Journal of Vegetation Science. 4(6):751-758.

Tardif, J., and Y. Bergeron. 1997. Comparative dendroclimatological analysis of two Black Ash and two white cedar populations from contrasting sites in the Lake Duparquet region, northwestern Quebec. Canadian Journal of Forest Research. 27(1):108-116.

Tardif, J., and Y. Bergeron 1999. Population dynamics of *Fraxinus nigra* in response flood-level variations, in northwestern Québec. Ecological Monographs. 61:107-125.

Taylor, S.M. 1971. Ecological separation and post-settlement habitat changes of *Fraxinus americana* and *Fraxinus pennsylvanica* in Washtenaw County, Michigan. American Journal of Botany. 58:466-467.

Taylor, R.A.J., T.M. Poland, L.S. Bauer, and R.A. Haack. 2005. Is Emerald Ash Borer an obligate migrant?. In: Mastro, V.C., R. Reardon and G. Parra (Eds.). Emerald Ash Borer Research and Technology Development Meeting. Forest Health Technology Enterprise Team, Morgantown WV. Pittsburgh PE. September 26-27, 2005. p. 14.

Telander, A.C., R.A. Slesak, A.W. D'Amato, B.J. Palik, K.N. Brooks, and C.F. Lenhart. 2015. Sap flow of Black Ash in wetland forests of northern Minnesota, USA: hydrologic implications of tree mortality due to emerald ash borer. Agricultural and Forest Meteorology. 206:4-11.

Thébaud, C., and M. Debussche. 1991. Rapid Invasion of *Fraxinus ornus* L. Along the Hérault River System in Southern France: The Importance of Seed Dispersal by Water. Journal of Biogeography 18: 7-12. DOI: 10.2307/2845240. Web site: http://www.jstor.org/stable/2845240

Thompson, I.D., W.J. Curran, J.A. Hancock, and C.E. Butler. 1992. Influence of moose browsing on successional forest growth on black spruce sites in Newfoundland. Forest Ecology and Management. 47(1-4):29-37.

Thompson, I.D., and W.J. Curran. 1993. A reexamination of moose damage to balsam fir–white birch forests in central Newfoundland: 27 years later. Canadian Journal of Forest Research. 23(7):1388-1395.

Thompson, D.G., and D. Pitt. 2011. Frequently Asked Questions (FAQs) On the Use of Herbicides in Canadian Forest. Frontline Technical Note 112. Canadian Forest Service, Great Lakes Forestry Centre, Ontario. 7 pp.

Tingley, M.W., D.A. Orwig, R. Field, and G. Motzkin. 2002. Avian response to removal of a forest dominant: consequences of hemlock woolly adelgid infestations. Journal of Biogeography. 29:1505-1516.

Tluczek, A.R., D.G. McCullough, and T.M. Poland. 2011. Influence of host stress on emerald ash borer (Coleoptera:Buprestidae) adult density, development, and distribution in *Fraxinus pennsylvanica* trees. Environmental Entomology. 40:357-366.

Tremblay, J.-P. pers. comm. 2017. February 2017. Email correspondence with C.S. Blaney, concerning the distribution, abundance and status of Black Ash on Anticosti Island, QC. Professor, Centre for Northern Studies, Centre for Forest Research, Université Laval, Quebec QC.

Trial, H. (Jr.), and M.E. Devine. 1994. Forest health monitoring evaluation: brown ash (*Fraxinus nigra*) in Maine. A survey of occurrence and health. Tech. Rep. No. 33. Maine Forest Service, Insect and Disease Management Division, Augusta, Maine.

Tuttle, J.P. 2007. The Hawk Moths of North America: A Natural History Study of the Sphingidae of the United States and Canada. The Wedge Entomological Research Foundation, Washington DC. 253 pp.

Uhlig, P., pers. comm. 2017. Email correspondence with C.S. Blaney, concerning the distribution and frequency of Black Ash in northern Ontario. February 23, 2017. Ecologist, Ontario Forest Research Institute, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie ON.

USDA NRCS. 2002. Green ash *Fraxinus pensylvannicus* Marsh. Plant Fact Sheet. US Department of Agriculture, Natural Resources Conservation Service. Web site: https://plants.usda.gov/factsheet/pdf/fs_frpe.pdf [accessed May 2016]

USDA NRCS. 2006. Black Ash *Fraxinus nigra* Marsh. Plant Fact Sheet. US Department of Agriculture, Natural Resources Conservation Service. Web site: https://plants.usda.gov/factsheet/pdf/fs_frni.pdf [accessed May 2016]

Vanstone, D.E., and L.J. LaCroix. 1975. Embryo immaturity and dormancy of Black Ash. Journal of the American Society for Horticultural Science. 100(6):630-632.

Van Grinsven, M.J., J.P. Shannon, J.C. Davis, N.W. Bolton, J.W. Wagenbrenner, R.K. Kolka, and T.G. Pypker. 2017. Source water contributions and hydrologic responses to simulated emerald ash borer infestations in depressional black ash wetlands. Ecohydrology. DOI: 10.1002/eco.1862

Venette, R.C., and M. Abrahamson. 2010. Cold hardiness of emerald ash borer, Agrilus planipennis: a new perspective. In: Black Ash Symposium: Proceedings of the Meeting. May. pp. 25-27.

Villari, C., J.G.A. Whitehill, D.F. Cipollini, D.A. Herms, and P. Bonello. 2014. Mechanism of ash resistance to emerald ash borer: progress and gaps. In: Buck, J., G. Parra, D. Lance, R. Reardon and D. Binion (Eds.). 2014 Emerald Ash Borer National Research and Technology Development Meeting. Ohio Agricultural Research and Development Center, Wooster OH. October 15-16, 2014. p. 8

Wagner, D.L., and K. Todd. 2015. Ecological impacts of the emerald ash borer. Pp. 15-63 in: R.G. Van Driesche (Ed.). Biology and Control of Emerald Ash Borer. US Department of Agriculture Technical Bulletin FHTET-2014-09. Morgantown, WV.

Wallander, E. 2008. Systematics of *Fraxinus* (Oleaceae) and evolution of dioecy. Plant Systematics and Evolution. 273:25-49.

Wallander, E., 2013. Systematics and floral evolution in *Fraxinus* (Oleaceae). Belgishe Dendrologie Belge 2012:38-58

Ward, K., M. Ostry, R. Venette, B. Palik, M. Hansen, and M. Hatfield, M. 2006. Assessment of Black Ash (*Fraxinus nigra*) decline in Minnesota. In: Proceedings of the 8th Annual Forest Inventory and Analysis Symposium. October 16, 2006. pp. 16-19.

Weed, A.S., M.P. Ayres, and J.A. Hicke. 2013. Consequences of climate change for biotic disturbances in North American forests. Ecological Monographs. 83(4):441-470.

Wilson, M.A. 2004. Emerald Ash Borer (*Agrilus planipennis*) biology and behavior. In: Proceedings of the Midwest Emerald Ash Borer Symposium, Novi MI.

Watkins, L. pers. comm. 2017. May 2016 and January 2017. Email correspondence with D.M. Mazerolle and C.S. Blaney, concerning distribution, abundance and standing timber volume of Black Ash in Ontario. Forest Analyst, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie ON.

Watkins, L. pers. comm. 2018. March 5, 2018. Email correspondence with C.S. Blaney, providing standing timber volume of ash in Ontario by Forest Management Unit. Forest Analyst, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie ON.

Wentzell, C., pers. comm. 2017. February 2017. Email correspondence with D.M. Mazerolle, concerning the impact of moose browsing on Black Ash in Gros Morne National Park, NL. Resource Management Officer, Parks Canada, Western Newfoundland & Labrador Field Unit, Rocky Harbour NL.

White, M.A. 2012. Long-term effects of deer browsing: Composition, structure and productivity in a northeastern Minnesota old-growth forest. Forest Ecology and Management. 269:222–228.

Willow, A.J. 2011. Indigenizing invasive species management: native North Americans and the Emerald Ash Borer (EAB) beetle. Culture, Agriculture, Food and Environment. 33(2):70-82.

Willoughby, I. 1999. Control of coppice regrowth in roadside woodlands. Forestry. 72(4):305-312.

Wilson, R. pers. comm. 2017. February 2017. Telephone correspondence with C.S. Blaney, concerning the severity of Emerald Ash Borer damage on Black Ash in Ontario and observed Black Ash population decline. Forest Program Pathologist, Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie, ON.

Woodcock, H., W.A. Patterson (Jr.), and K.M. Davies (Jr.). 1993. The relationship between site factors and white ash (*Fraxinus americana* L.) decline in Massachusetts. Forest Ecology and Management. 60:271-290.

Wright, J.W. 1953. Notes on flowering and fruiting of northeastern trees. Station Paper No. 60. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. Upper Darby, PA. 38 pp.

Wright, J.W., and M.H. Rauscher. 1990. *Fraxinus nigra* Marsh. Black Ash. In: Burns, R.M. and B.H. Honkala (technical coordinators). Silvics of North America: Vol. 2. Hardwoods. Agriculture Handbook 654. US Department of Agriculture, Forest Service. Washington DC. pp. 344-347. Web site: https://www.na.fs.fed.us/spfo/pubs/silvics_manual/volume_2/fraxinus/nigra.htm

Melissa B. Youngquist, M.B., S.L. Eggert, A.W. D'Amato, B.J. Palik, and R.A. Slesak. 2017. Potential Effects of Foundation Species Loss on Wetland Communities: A Case Study of Black Ash Wetlands Threatened by Emerald Ash Borer. Wetlands 37: 787–799.

Zhao Y.-J., T. Hosoya, H.O. Baral, K. Hosaka, and M. Kakishima. 2012. *Hymenoscyphus pseudoalbidus*, the correct name for *Lambertella albida*, reported from Japan. Mycotaxon. 122:25-41.

Zoladeski, C.A., R.J. Delorme, and G.M. Wickware. 1998. Forest ecosystem toposequences in Manitoba. Special Report 12. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. 63 pp.

Zogg, G.P., and V.B. Barnes. 1995. Ecological classification and analysis of wetland ecosystems, northern Lower Michigan, U.S.A. Canadian Journal of Forest Research. 25:1865-1875.

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

David Mazerolle holds an undergraduate degree in Biology and a Master's degree in Environmental Studies from the Université de Moncton, where he studied the biogeography of exotic vegetation in relation to habitat and disturbance regimes, producing an exotic invasive vegetation management strategy for Kouchibouguac National Park, on New Brunswick's eastern shore. After various research assistant positions, he worked from 2003 to 2005 as coordinator for plant survey and monitoring projects at the Bouctouche Dune Eco-centre, focusing on the rare coastal plants of New Brunswick's Northumberland Coast, including several species at risk. Since 2006, David has worked as a botanist for the Atlantic Canada Conservation Data Centre, a position that requires extensive knowledge on the region's flora, including both native and exotic species. An accomplished field botanist, he has over fifteen years' experience working on various research, survey and monitoring projects and has authored and coauthored a large number of technical reports pertaining to rare plants in Atlantic Canada as well as numerous national and provincial species at risk status reports.

Sean Blaney is the Executive Director and Senior Scientist of the AC CDC, where he is responsible for maintaining status ranks and a rare plant occurrence database for plants in each of the three Maritime provinces. Since beginning with the AC CDC in 1999, he has discovered dozens of new provincial records for vascular plants and documented over

15,000 rare plant occurrences during extensive fieldwork across the Maritimes. Sean is a member of the COSEWIC Vascular Plant Species Specialist Committee, the Nova Scotia Atlantic Coastal Plain Flora Recovery Team, and has written or co-written numerous COSEWIC and provincial status reports. Prior to employment with AC CDC, Sean received a B.Sc. in Biology (Botany Minor) from the University of Guelph and an M.Sc. in Plant Ecology from the University of Toronto, and he spent eight summers as a naturalist in Algonquin Provincial Park, where he co-authored the second edition of the park's plant checklist.

Donna Hurlburt holds a B.Sc. (Agriculture) (Nova Scotia Agricultural College, Truro, N.S.), an M.Sc. in Biology (Acadia University, Wolfville, NS) and a Ph.D. in Environmental Biology and Ecology (University of Alberta, Edmonton, AB). Her Ph.D. on Soapweed (*Yucca glauca*) – yucca moth mutualisms in southeast Alberta was followed by an NSERC Industrial Post-doctoral Fellowship with Abitibi-Bowater in Nova Scotia on forestry regulations in treed peatlands. She owns and operates an environmental consulting business in Annapolis Royal, Nova Scotia, where a significant portion of her work serves to bridge the gaps between indigenous knowledge and scientific knowledge, particularly as it relates to environmental decision making. She holds extensive experience working with species at risk across Canada, including a long-term affiliation with COSEWIC. Donna has participated on several COSEWIC Subcommittees, including the Arthropods and Vascular Plants Specialist Subcommittees and was an appointed member of COSEWIC. She was an Aboriginal Traditional Knowledge Subcommittee Co-chair from 2011-2018. Donna has written a provincial status report on Black Ash, has prepared several Aboriginal traditional knowledge-based reports on the species nationally and is engaged with the province of Nova Scotia and the Mi’kmaq on recovery initiatives.

COLLECTIONS EXAMINED

Black Ash records from major Atlantic Canadian herbaria have been well databased and were available for this report. Additional herbarium data were obtained via the Canadensys (2016) database.

Appendix 1. IUCN Threats Calculation of Black Ash.

THREATS ASSESSMENT WORKSHEET

Species or Ecosystem Scientific Name	Black Ash (*Fraxinus nigra*); Wisqoq (Mi'kmaq); Wikp (Maliseet); Ehsa (Mohawk); Aagimaak (Ojibway)				
Element ID			**Elcode**		
Date (Ctrl + ";" for today's date):	11/09/20 17				
Assessor(s):	D Benoit, J Vamosi, D Fraser, S Blaney, D Hurlburt, D Mazerole, J Labreque, E Fay, J McNight, C Hamel, M Sabine, D Carleton, K Picard, S Meades, B Tucker, J Humber, J Whitton, V Brownell, B Bennett, M Ballard, N Jones, K Timm				
References:					

Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	1	1
D	Low	1	1
Calculated Overall Threat Impact:		Medium	Medium

Assigned Overall Threat Impact:	Medium
Impact Adjustment Reasons:	
Overall Threat Comments	Almost all population is in ON, QC and NB (roughly 59.6% in ON, 25.4% in QC, and 15.0% in NB). Abundance is concentrated away from peripheries; restricted to floodplains at northern margin and largely lost to agricultural and urban conversion along southern margin of Canadian range. Provincially rare in MB, NS, PE and NF. Situation in ON, QC and NB will drive the story. Generation time of ~60 years, can reproduce at 30, can live to 200-300 years. Avg age of reproducing individuals of 60 years is a reasonable estimate. Emerald Ash Borer has not yet changed this significantly within Canada but could do so in future.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Moderate (11-30%)	High (Continuing)	Housing and urban development continues to expand in all areas of Black Ash distribution, but a very low portion of overall occupied area is affected annually. This could compound over three generations (180 years) to more than 11% population loss. Severity is moderate, because where it happens, it means removal of trees.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	
1.3	Tourism & recreation areas						Not applicable, Cottages were considered under housing.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Historical wetland losses are estimated to be about 70% in southern Ontario (mostly from agriculture, at least initially) but current and expected future rates of loss to agricultural conversion are believed to be low.
2.2	Wood & pulp plantations					All forestry impacts are dealt with under 5.3 Logging and wood harvesting
2.3	Livestock farming & ranching	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Some minor cattle grazing in riparian areas that harbour Black Ash, trivial at a national scale.
2.4	Marine & freshwater aquaculture					
3	Energy production & mining	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Areas with Black Ash that might be affected by oil and gas extraction are trivial in relation to the national range. Decision on fracking near some Black Ash sites in Nova Scotia, Quebec anticipated in next 2 years; Windsor Energy Inc. was granted a five-year lease to continue exploring for oil and gas in southern New Brunswick (in April 2012); Exploration around the St. Lawrence and Gaspe Peninsula of Quebec. Recent moratorium on fracking in NB has been extended indefinitely.
3.2	Mining & quarrying	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Areas with Black Ash that might be affected by mining are trivial in relation to the national range. Nova Scotia: DDV Gold wants to develop an open pit mine in the Moose River area, near Middle Musquodoboit, opening in 2013. New Brunswick: proposed tungsten and molybdenum open pit mine jointly owned by Northcliff Resources Ltd. and Geodex Minerals Ltd. If approved, the mine would be constructed 60 kilometres northwest of Fredericton, New Brunswick; Sisson Mine development underway in New Brunswick.
3.3	Renewable energy	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Areas with Black Ash that might be affected by renewable energy development are trivial in relation to the national range. Some relatively small hydro development anticipated in southern Ontario and Quebec in the next decade (based on ongoing environmental assessments); no major development expected in Nova Scotia, insular Newfoundland or New Brunswick. New Brunswick may see more wind turbines.
4	Transportation & service corridors	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
4.1	Roads & railroads	Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Areas with Black Ash that might be affected by road and railway development and maintenance are trivial in relation to the national range. Road development continues to result in destruction of Black Ash habitat and trees. In Nova Scotia, a number of recent records have been reported through Environmental Assessment processes associated with road expansion in Nova Scotia. In areas of interest to the Mi'kmaq, EAs are required to identify the location of Black Ash and to often provide mitigation.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.2	Utility & service lines		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Areas with Black Ash that might be affected by utility and service lines are trivial in relation to the national range. Some Black Ash individuals and stands are likely destroyed through the development of new utility and service lines, most likely in areas of new hydro development. Any regrowth under lines would not reach reproductive size.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Medicinal uses - sap, leaves, bark, seeds (Arnson 1981; College of Menominee Nation Sustainable Development Institute and U.S. Department of Agriculture Forest Service No date; Fox No Date; Garrick 2012; George No Date). Indigenous use for basketry results in the loss of whole tree but is not a significant factor at the national scale. For other uses, only parts of the tree are used.
5.3	Logging & wood harvesting	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Some use of the wood by the forest industry, but most cutting would be incidental harvest by industrial forestry operations that are primarily targeting co-occurring species. This is very prevalent across much of the species' range. Current rates compound to an area of about 47.6% of Black Ash's Canadian Range over three generations. Black Ash generally has fairly good to good regeneration potential, but post-harvest use of herbicides to reduce broad-leaved regeneration would limit the species where it is practiced (~0.05% of Black Ash's Canadian range annually, no more than 10% impacts over three generations). Forestry impacts on Black Ash are somewhat mitigated by its tendency to occur in wetlands and along watercourses in which cutting is more regulated. Given the extent of forestry, even a small but consistent decline in its abundance in post-harvest regeneration would add up to a non-trivial loss over three generations. Non-timber forest products - Some targeted harvesting of species for firewood and for basketry, veneers, trims, often for Aboriginal purposes (George No Date). Historically, at least in Nova Scotia, decline of species has been attributed to harvest of saplings for barrel staves (Hill-Forde 2004) http://www.americanindian.si.edu/environment/pdf/transcripts/01_02_Akwesasne_Mohawk_People.pdf. Shading by other species limits recruitment; i.e., probably can tolerate some surrounding harvest. Scope is at the low end of the given 1-10% range.
5.4	Fishing & harvesting aquatic resources						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6	Human intrusions & disturbance						
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Recruitment limited by fire (seedlings not fire resistant) (Batzer and Baldwin 2012) "Black ash is easily damaged by fire and can be killed or top-killed by severe fire but it probably sprouts from the root crown following such damage. Burned sites also may be re-colonized through the wind-dispersed seed." (USDA 2006). Black Ash has a good seed bank and regenerates well; it is shade tolerant and prefers wet areas in habitats where fire is much less frequent. It is not especially fire tolerant but does sprout vigorously from base, and also good dispersal from adjacent areas post-fire.
7.2	Dams & water management/use		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Riparian species so likely tolerant of some fluctuations in water level, but major long-term water level increases from damming would eliminate subpopulations (e.g., the virtual disappearance of Black Ash on Lake Abitibi following construction of a hydroelectric dam at Iroquois Falls, QC around 1915-1920) http://web2.uqat.ca/ferld/recherche/frenenoir_e.htm. Currently, there are no usable Black Ash trees at Akwesasne. Most of the traditional lands were flooded for a dam project in the 1830s, construction of the St. Lawrence Seaway in the 1950s and other hydroelectric projects (Natural Resources Canada 1997). Other historical losses from large and small dams would be extensive but not relevant to the score here looking into the future. There is no evidence of specific future dams that may cause effects. Some small-scale dams likely.
7.3	Other ecosystem modifications		Not a Threat	Negligible (<1%)	Neutral or Potential Benefit	High (Continuing)	Black Ash is susceptible in areas of new beaver dams where land may be flooded. Therefore, if human management of beavers is not in place, there may be a temporary negative impact. However, beaver dams are not typically a permanent feature when considered over 3 generations (180 years) and beavers are considered only a natural limiting factor. (Beavers eating Black Ash would be considered in category 8.2, if it were considered a threat, which it is not.)

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	Invasive & other problematic species & genes	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	C	Medium	Restricted (11-30%)	Extreme (71-100%)	High (Continuing)	Emerald Ash Borer (EAB; *Agrilus planipennis* Fairmaire), a phloem-feeding beetle native to Asia, was discovered near Detroit, Michigan and Windsor, Ontario in 2002. It has since spread as far as Winnipeg, Manitoba and Edmundston, New Brunswick within Canada and through most of area of the eastern USA in which ash occurs. Smitley *et al*. (2008) estimated that ash decline moved outward from a point of infestation at a rate of 10.6 km per year. The beetles have been noted spreading at rates up to 30-40 km/year (but 20 km/year is a typically used estimate) and human assisted transport can create infestations hundreds of km beyond EAB core range. No Canadian Black Ash occurrences are more than 1,300 km from currently affected areas, which is less than the distance EAB has already covered from Detroit-Windsor to the peripheries of its current distribution. Evidence from U.S. Forest Service Forest Inventory and Analysis plots suggests that catastrophic ash mortality in a county becomes apparent about five years after an infestation has been detected there (Liebhold *et al*. unpublished data in Kovacs *et al*. 2010). 99% mortality of all ash species was recorded in a large Michigan study, and Black Ash is the most susceptible of all eastern ash species. It is uncertain where northern limit of EAB will be in 10 years extensive spread is expectable. EAB does not yet cover 30% of the range. EAB impacted areas are well-tracked in Ontario, but there is very little quantification on numbers of trees lost. Potential mitigating factors in EAB spread: 1) Colder climates (-30 minimum winter temperatures), which may protect large portions of the northern range though limits of tolerance are incompletely understood and climate change is likely to move tolerance zones northward); 2) Parasitoid biocontrol introductions, which have been shown to significantly reduce EAB productivity with as yet unknown effects on ash mortality. The Threat Calculator group also discussed potential differences in spread of EAB in cities vs other heavily forested regions, but the suggestion that EAB may spread less rapidly in continuous forest is untested.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species/diseases		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	No native species are considered to be threats, as opposed to limiting factors. The Canadian Forestry Service's National Forest Health and Biodiversity Database has catalogued over 30 species of insects, fungi and diseases which have affected Black Ash in Atlantic Canada. Through surveys completed by the First Nations Forestry Program in Nova Scotia Black Ash has been known to be affected by anthracnose, heart rot, ice, hail and fall webworm as well as other unknown insects affecting foliage (Hudson 2003). Predators of Black Ash include song and game birds and wood ducks which eat Black Ash seed and White-tailed Deer, Moose and Beaver which browse Black Ash branches and twigs (Burns and Honkala 1990). Browsing by White tailed deer may be significant in some areas within the southern part of the range as is the case with Moose in northern Cape Breton. These are, however, non-significant on the national scale. Note that introduced Moose on the Island of Newfoundland and White-tailed Deer on Anticosti Island, Quebec are considered as invasive non-native species threats above.
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin		Unknown	Unknown	Unknown	High (Continuing)	Conclusive evidence of the cause of Black Ash decline and poor health in Nova Scotia, adjacent New Brunswick and Prince Edward Island is lacking. There is limited but fairly strong evidence of major declines in Nova Scotia since the 1950s and very few healthy and reproductive trees are found in Nova Scotia today. Permanent sample plot data suggests almost no recruitment into reproductive sizes. This may be due to the leaf damaging effects of Cottony Ash Psyllid (*Psyllopsis discrepans*), an aphid-like homopteran insect native to Europe that uses European Ash as a major host species (*Ossiannilsson* 1992), and/or due to an introduced disease that insect transmits. This insect is known from Nova Scotia, is known to have major effects on planted Black Ash in the prairies, and causes curled leaves, a symptom often associated with low vigour trees in the Maritimes. Whatever is causing low vigour and decline in the region could represent a significant threat for the remainder of the range, were it to spread. This disease agent may also be associated with the Black Ash declines elsewhere in the northeast that are called "ash dieback" but are not conclusive attributed to any cause.
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9	Pollution		Negligible	Negligible (<1%)	Unknown	High (Continuing)	ATK makes some general statements about pollution contributing to the decline of Black ash p://www.americanindian.si.edu/environment/pdf/transcripts/01_04_Akwesasne_Mohawk_Challenge.pdf)
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						Herbicides from forestry were considered but scored above under forestry 2.1
9.4	Garbage & solid waste		Negligible	Negligible (<1%)	Unknown	High (Continuing)	ATK from Akwesasne suggests that dumping in Black Ash habitat is an issue (http://www.americanindian.si.edu/environment/pdf/transcripts/01_04_Akwesasne_Mohawk_Challenge.pdf). This is not a major factor across the Canadian range.
9.5	Air-borne pollutants						There has been speculation that acid rain or other airborne pollutants are contributing to Black Ash decline. They could be a contributing factor, but there is no direct evidence on effects of air borne pollutants in relation to the observed poor health of Black Ash reported in Maine, Nova Scotia and elsewhere since at least 1992 (Trial and Devine 1992).
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Negligible	Negligible (<1%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration		Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs/3 gen)	The Mi'kmaq in CEPI (2006) attribute the decline of Black Ash around the Bras d'Or Lakes in Cape Breton, Nova Scotia to climate change because it alters germination conditions. One detailed modelling study (Morin *et al*. 2008) has suggested major retraction of Black Ash range over the next 100 years in response to climate change (more than any other tree species studied), but they did not use accurate current northern range limits for the species and all climate-range shift models have considerable uncertainty. Likely climate change effects over the short and long term remain poorly understood.
11.2	Droughts						Drought was considered but not scored. Not separable from climate change.
11.3	Temperature extremes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding		Negligible	Negligible (<1%)	Unknown	High (Continuing)	Not significant at the national scale. Some blow down of trees reported in southwest Nova Scotia (Hill-Forde 2004). Black Ash is resistant to temporary flooding occurrences. Indigenous communities in Manitoba have seen large scale flooding because of human-made decisions on water levels being kept high for hydroelectric power generation.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							