COSEWIC
Assessment and Status Report

on the

Blue Ash
Fraxinus quadrangulata

in Canada

THREATENED
2014

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:

COSEWIC. 2014. COSEWIC assessment and status report on the Blue Ash *Fraxinus quadrangulata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 58 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2000. COSEWIC assessment and update status report on the blue ash *Fraxinus quadrangulata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 11 pp.

White, D.J., and M.J. Oldham. 2000. Update COSEWIC status report on the blue ash *Fraxinus quadrangulata* in Canada, *in* COSEWIC assessment and update status report on the blue ash *Fraxinus quadrangulata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-11 pp.

Ambrose J.D., and S.W. Aboud. 1983. COSEWIC status report on the blue ash *Fraxinus quadrangulata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 27 pp.

Production note:
COSEWIC would like to acknowledge David A. Kirk (Aquila Conservation and Environment Consulting) for writing the status report on Blue Ash, *Fraxinus quadrangulata***,** in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Jeannette Whitton and Bruce Bennett, Co-chairs of the COSEWIC Vascular Plants Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Frêne bleu (*Fraxinus quadrangulata*) au Canada.

Cover illustration/photo:
Blue Ash — Photo by ©John D. Ambrose.

Catalogue No. CW69-14/266-2015E-PDF
ISBN 978-1-100-23242-3

COSEWIC
Assessment Summary

Assessment Summary – November 2014

Common name
Blue Ash

Scientific name
Fraxinus quadrangulata

Status
Threatened

Reason for designation
This tree has a restricted distribution in the Carolinian forests of southwestern Ontario. Small total population size in a fragmented landscape, combined with increasing potential impact from browsing by White-tailed Deer and infestation by the invasive Emerald Ash Borer, place the species at risk of further declines at most sites. In addition, mature trees on Middle Island are threatened by impacts of nesting Double-crested Cormorants. These factors resulted in a change in status from Special Concern to Threatened.

Occurrence
Ontario

Status history
Designated Threatened in April 1983. Status re-examined and designated Special Concern in November 2000. Status re-examined and designated Threatened in November 2014.

COSEWIC
Executive Summary

Blue Ash
Fraxinus quadrangulata

Wildlife Species Description and Significance

Blue Ash is a medium-sized tree, roughly 20 m in height and up to 80 cm in diameter, and is one of six ash species native to Canada. The trunk can be straight or irregular and the crown is narrow, small and rounded. Trees have light-coloured, reddish-grey or tan-grey, scaly bark. The leaves are compound and opposite with seven (5-11) leaflets and the twigs have square sides with four distinctive corky ridges or wings (hence the scientific epithet *quadrangulata*). Clusters of small flowers that lack petals are produced in spring, as new leaves are expanding. The fruits are single-seeded samaras that are usually twisted, with a notch in the broad wing. A distinctive feature is the retention of dead lower branches, giving the tree an untidy appearance. The inner bark contains a sticky substance that turns blue upon exposure to air (hence the species' common name).

Distribution

Blue Ash has a restricted distribution in Canada and occurs only in southwestern Ontario in the counties and municipalities of Elgin, Middlesex, Lambton, Chatham-Kent and Essex. It is found at Point Pelee, Peche Island at the mouth of the Detroit River, and the Erie Islands, as well as in river valleys along the Thames River, Sydenham River, and Catfish Creek. Blue Ash is more widely distributed in the United States, and ranges from Ohio south into Alabama, Georgia and Arkansas and west to Wisconsin, Oklahoma and Kansas.

Habitat

Blue Ash grows in a variety of habitats and soil types. In Ontario, it is found in three distinctive habitat types. They include floodplains and river valleys where Blue Ash grows in rich soils in association with a variety of other tree species; shallow soils on alvar and limestone on the Lake Erie Islands; and stabilized beaches at Point Pelee National Park, and Fish Point on Pelee Island. All of these habitats have declined in area and quality over the last 100 years. While the effects of habitat fragmentation on Blue Ash have not been assessed, it is expected that fragmentation will result in ecological degradation and perhaps genetic degradation over a longer timeframe, which may contribute to decreasing the likelihood of persistence of subpopulations.

Biology

Unlike other ash species, flowers of Blue Ash include both male and female reproductive structures. The species reproduces by seed and there is no evidence of clonal spread. Blue Ash trees can live up to 300 years (typically 150 to 200 years) and age of maturity (fruiting age) is approximately 25 years. Seed crops are produced every 3-4 years and seeds are dispersed by wind. Most seeds likely disperse within 10 m of the parental tree, but a small number of seeds may travel up to 200 m. Seeds may be dispersed over larger distances by water or animal transport.

Population Sizes and Trends

In 1983, 14 sites with Blue Ash trees were reported within four regions of southwestern Ontario. By 2000, additional searches resulted in recognition of a total of 37 extant subpopulations. In 2001, an additional 19 sites were documented; combining with the 37 subpopulations above this gives a total of 56 sites. The total Canadian population was estimated at fewer than 1000 mature trees in 2001. Fieldwork conducted during 2012/2013 suggests that Blue Ash is more abundant than previously documented. Information on about half of the known sites was collated (n=26) and 1806 trees were counted. Of these trees, 708 (39%) were considered mature (capable of bearing seed). Large numbers of seedlings and saplings were observed at some sites, especially at Point Pelee National Park, and the McAlpine Tract on the Sydenham River.

Threats and Limiting Factors

Since the last status assessment, the potential for deer browsing to impact recruitment and establishment of Blue Ash has emerged as a greater concern than previously noted. Although a few surveyed sites had very large numbers of seedlings and young trees, at many surveyed sites there was little evidence of regeneration suggesting that deer browsing could be preventing establishment of young trees. In addition, the invasive alien beetle Emerald Ash Borer (EAB) has emerged as a new threat to native ash species, including Blue Ash. First detected in North America in 2002, EAB has since spread rapidly. During surveys in 2012/2013, signs of EAB were found at 45.8% (11 out of 26) of the sites and in 70 (3.7%) Blue Ash trees. Although few Blue Ash trees appear to have been killed so far by EAB (0.26% of surveyed trees) and they appear to show resistance, it is unknown whether the impact of EAB will increase in the future. Additional threats to Blue Ash include forest management practices that may include direct cutting of Blue Ash trees because of misidentification by landowners, or authorities – either deliberately or because of EAB-related management; alteration to natural disturbance regimes through fire suppression and water management; impacts of livestock farming and ranching including grazing and trampling in riparian habitats; recreational activities (e.g., all-terrain vehicles in local areas), which could impact regeneration through trampling; and, at Middle Island, nitrification of soils and damage to trees from Double-crested Cormorant guano and nesting activities.

Protection, Status, and Ranks

COSEWIC first assessed Blue Ash as Special Concern in April 1983, confirmed same status in November 2000, and the wildlife species was last assessed Threatened in November 2014. Blue Ash is listed as ‘Special Concern’ under Canada’s *Species at Risk Act*, 2003 and under Ontario’s *Endangered Species Act*, 2007. Although Blue Ash is considered globally secure (G5) and nationally secure in the United States (N5), it is considered vulnerable (N3) in Canada and is not ranked in Ontario (S3?). Blue Ash is listed as critically imperiled (S1) in Pennsylvania, West Virginia, Wisconsin and Iowa, as imperiled (S2) in Kansas and Mississippi, and vulnerable (S3) in Virginia. It is listed as critically imperiled to imperiled (S1S2) in Georgia and as imperiled to vulnerable (S2S3) in Oklahoma. It is not ranked (SNR) in all other states where it occurs.

TECHNICAL SUMMARY

Fraxinus quadrangulata

Blue Ash Frêne bleu

Range of occurrence in Canada: Ontario

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 (2008) is being used) Average age of mature trees estimated using growth correction factors and the sample of trees (> 10 cm dbh) surveyed in 2012/2013; average age varied from 51 years from growth rates calculated from trees on the Sydenham River to 70-105 years (growth correction factor 4.5 average of White Ash and Green Ash).	50-100 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? There is evidence of low levels of mortality due to impacts of Emerald Ash Borer, which has been present within the range of the species for 11 years. Conversion of forests to agriculture and urban areas also continues to decrease habitat and presumably removes trees.	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations] Projections are not possible because it is unclear whether uninfested trees are resistant to EAB or have simply not been attacked to date.	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. Over the last 150-300 years (3 generations), there have been declines in forest cover in southwestern Ontario, some of which may have resulted in habitat loss and increased fragmentation of sites where Blue Ash occurs.	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. Based on information from surveys declines from Emerald Ash Borer are not predicted; however, this needs to be monitored.	Unknown
[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.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	8,884 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	272 km²
Is the population severely fragmented? Most sites where Blue Ash occurs are small in size and separated by large distances and are thus highly fragmented. However, the dispersal distances of Blue Ash are unknown as are the minimum patch sizes and inter-patch distances to support a viable population. Thus although fragmentation may cause declines in habitat quality its effects on genetics and dispersal and viability of subpopulations are unknown.	Uncertain
Number of locations Locations are defined by the most significant threats at each site as follows: 1. Middle Island: threat of nesting cormorants. (1 location) 2. All sites are potentially affected by deer browsing, except those on Pelee Island and Middle Island where there are no deer. The number of locations could vary from 1-many depending upon the potential for effective management of deer subpopulations, but the case can be made for 3 management units (3 locations) 3. All sites are impacted by Emerald Ash Borer, which could likely act similarly across all sites, but this threat is only considered the most significant threat at Pelee Island (1 location). (Alternatively, 2 locations are obtained if Emerald Ash Borer is the most significant threat)	5 (or 2) - >10
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? No subpopulations are known to have been lost.	No
Is there an [observed, inferred, or projected] continuing decline in number of populations? No subpopulations are known to have been lost since the last assessment.	No
Is there an [observed, inferred, or projected] continuing decline in number of locations?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? The presence of abundant Deer and Emerald Ash Borer reduce the quality of the habitat of Blue Ash.	Yes
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

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
Based on the 26 sites surveyed in preparation of this report, and using a dbh> 10 cm to designate mature individuals. Trees within the City of Windsor are excluded (see **Canadian Range)**	708
Total Assuming that most occurrences have been documented, the total number of mature individuals is unlikely to exceed 2,500. However, it is possible that additional search effort could result in a total above this threshold.	Not likely to exceed 2,500

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done

Threats (actual or imminent, to populations or habitats)

The most significant threats to Blue Ash are:

1. Problematic Native Species: Impacts of White-tailed Deer (High-Low Impact)
2. Invasive Species: Emerald Ash Borer (Medium-Low Impact)
3. Other Problematic Species: Double-crested Cormorants on Middle Island (Negligible Impact; localized, but greatest threat to Middle Island subpopulation)
4. Natural Systems Modification: Fire Suppression and Water Management (Negligible Impact)
5. Livestock Farming and Ranching: Grazing and Trampling by Cattle, Horses and Sheep (Negligible Impact)

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Nationally secure in the United States (N5), (S5) in Kentucky. Critically imperiled (S1) in Pennsylvania, West Virginia, Wisconsin and Iowa, as imperiled (S2) in Kansas, and Mississippi, and vulnerable (S3) in Virginia. It is listed as S1S2 in Georgia and as S2S3 in Oklahoma. Unranked (not yet assessed) in Michigan, Alabama, Missouri, Ohio, Minnesota, Texas, Arkansas, Illinois, Tennessee, and Indiana.	
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Limited
Is rescue from outside populations likely? Natural dispersal may occur infrequently between the nearest occurrences in the U.S. and the southernmost occurrences in Canada.	Possible

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Threatened in April 1983. Status re-examined and designated Special Concern in November 2000. Status re-examined and designated Threatened in November 2014.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric code:** C2a(i)
Reasons for designation: This tree has a restricted distribution in the Carolinian forests of southwestern Ontario. Small total population size in a fragmented landscape, combined with increasing potential impact from browsing by White-tailed Deer and infestation by the invasive Emerald Ash Borer, place the species at risk of further declines at most sites. In addition, mature trees on Middle Island are threatened by impacts of nesting Double-crested Cormorants. These factors resulted in a change in status from Special Concern to Threatened.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met. Monitoring data are insufficient to allow quantification of declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): May meet Threatened B2ab(iii,v); EO and IAO are below thresholds, but evidence for severe fragmentation is not conclusive, and the number of locations is difficult to establish, but expected to exceed 10. There are no extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened C2a(i) with fewer than 10,000 total individuals and no sites with more than 1000 mature individuals. Declines in the number of mature individuals have been documented and are projected to continue.
Criterion D (Very Small or Restricted Population): Not met. Complete surveys of known subpopulations are expected to exceed 1000 mature individuals.
Criterion E (Quantitative Analysis): Not met. No quantitative analysis.

PREFACE

In light of an important new threat to ash trees (Emerald Ash Borer *Agripus planipennis* EAB) surveys were carried out in 2012/2013 to evaluate the impact on Blue Ash at about half of the known sites (n=26). Although this invasive insect was found at 46% of sites, few trees (3.7% of 1889) were infested by EAB. Levels of infestation varied by site and were generally higher in the areas closer to the original epicentre of invasion (Pelee Island, McKeough Dam). Blue Ash in Ontario appears to survive attacks by EAB and only eight trees were found dead. The impact of EAB may depend on the proximity, numbers, and age structure of other ash species. It is predicted that the full impacts of EAB on Blue Ash will not be seen for a further 3-5 years at which time sites should be re-inventoried. Since the 2000 assessment of the Blue Ash (COSEWIC 2000), some new sites have been discovered, and additional surveys indicate that the numbers of individuals at some existing sites is much larger than previously estimated. Some sites had extensive regeneration perhaps partly due to declines in livestock grazing pressure. The impact of White-tailed Deer on Blue Ash recruitment is unknown at this time; a preliminary analysis indicated no clear relationship between deer populations and trends estimated from harvest and sighting data and Blue Ash reproduction. This requires further investigation and long-term study plots (exclosures) to determine the impact of deer browsing.

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
(2014)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune
Canada

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

COSEWIC Status Report

on the

Blue Ash
Fraxinus quadrangulata

in Canada

2014

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific name: *Fraxinus quadrangulata* Michaux

Synonyms: None

English Common Names: Blue Ash, Four-angled Ash

French Common Names: Frêne bleu, Frêne anguleux, Frêne quadrangulaire

Classification:

Major Plant Group: Eudicot Flowering plant

Order: Lamilales

Family: Oleaceae (olive family)

Morphological Description

Blue Ash is a medium-sized tree with an irregular (sometimes straight) trunk, often reaching 20 m in height and a diameter of 50 cm or more (Waldron 2003). Trees up to 88 cm in diameter have been recorded from Ontario in recent surveys (Gard Otis, unpublished data; Kirk 2013). Some Blue Ash trees in the United States are much larger; the largest Blue Ash found there was in the Davey Woods Nature Preserve, Ohio by S. Galehouse in 2008 and was 34.7 m (113.9 feet) high and 222.3 cm (87.5 inches) in diameter (Eastern Native Tree Society 2013).

The following description is from the Ambrose and Aboud (1983), Farrar (1995), Waldron (2003), Ohio Department of Natural Resources (ODNR 2013), and Strobl and Bland (2013). While the crown can sometimes be irregularly shaped, most commonly it is rounded and narrow. In alvar habitat on Pelee Island, crowns of Blue Ash can be open and spreading. The bark is light grey and usually scaly to platy; as trees age the bark becomes more shingled in appearance. By contrast, the bark of most other ash tree species has a diamondback appearance usually with interlacing ridges and deep furrows. However, tree bark is often very variable and not in itself reliable for identification and this is also true in the case of Blue Ash (Craig, pers. comm. 2013). For example, the bark of mature Blue Ash trees sometimes has flat-topped ridges that do not quite interlace rather than the typical shingled appearance (ODNR 2013).

A distinctive feature in Blue Ash compared to other ash species is the retention of dead lower branches, giving the tree an untidy appearance. The twigs are greyish-brown with conspicuous ridges, giving them the appearance of having four sides (hence the specific epithet, *quadrangulata*). Blue ash seems to be rot-resistant and dead twigs and small branches may remain attached to the trunk and main limbs for many years after they die, giving the tree a very “twiggy” or messy appearance (Craig, pers. comm. 2013).

Leaves are opposite and compound, with 5-11 leaflets each. Leaflets are oval in shape, dark green above and lighter green underneath with coarsely toothed edges. Unlike other ash species in Ontario, Blue Ash leaves remain green until the fall and provide poor colours (usually pale yellow) compared to other ash species; moreover, the leaves are retained longer than in other ash species. During periodic drought conditions in alvar or limestone islands, Blue Ash leaves remain green when other tree leaves are browning or withering (Waldron 2003).

Flowers appear as small dense clusters that expand with the growth of new leaves in the spring. The single-seeded fruit, a samara, is twisted, flattened and broad-winged to the base and is distinct from other ash species (Waldron 2003). The inner bark contains a sticky substance that turns blue upon exposure to air (hence the species’ common name).

Population Spatial Structure and Variability

No genetic or morphological analyses have been conducted on the Canadian Blue Ash population. Although dispersal is by seed and principally by wind, it is likely that transport by water or possibly some bird species could disperse seeds over larger distances. This means that gene flow among subpopulations in Ontario and between those nearby in the United States and those in Ontario is possible. The closest naturally established Blue Ash trees in the United States occur on South Bass Island in Ohio, 12 km from Blue Ash sites on Pelee Island. However, the closest planted Blue Ash trees are in Detroit, 5 km or less from the planted trees in Windsor, Ontario.

Designatable Units

All Canadian occurrences of Blue Ash are within the Mixedwood Plains ecozone (Crins *et al.* 2009) and within the Deciduous Forest Region or Carolinian Forest life zone. Within the Mixedwood Plains ecozone, Blue Ash occurs in ecoregion 7E and within this ecoregion it occurs in three ecodistricts. These are: ecodistrict 7E-1 – which includes Point Pelee National Park, islands in Lake Erie, including Pelee Island, ecodistrict 7E-2 – which includes the Sydenham River, the Lower Thames River and Catfish Creek and ecodistrict 7E-6 – which includes parts of the Upper Thames River

There is a disjunction in the species’ Canadian range, between the Essex County sites and the sites in Elgin, Chatham-Kent, Lambton and Middlesex counties. However, Blue Ash probably occurred historically over the entire region, including the area that spans the current disjunction (prior to European settlement). Because the disjunction is not considered natural, DU designation is probably not warranted.

The occurrence of subpopulations in three distinct ecodistricts (see above) and in distinct habitats (alvar – Pelee Island or sandy soils – Pelee Island, Point Pelee National Park versus floodplain clay soils – Sydenham River, Thames River) suggests the possibility of differentiation among subpopulations occurring in different habitats with different ecological processes. Blue Ash growing on alvar sites could be more drought-tolerant and adapted to disturbance from periodic fires (at least historically, more recently prescribed burns). Blue Ash subpopulations in floodplains and river valleys might harbour unique adaptations to periodic flooding, and their recruitment dynamics determined by canopy openings that result from effects of storms and windthrows. It is possible that the local adaptations of Blue Ash in these two areas would therefore be distinct and perhaps unique.

Special Significance

Ash trees (*Fraxinus* spp.) are common and abundant in eastern North American forests and occur in 26 forest cover types (Burns and Honkala 1990; Cappaert *et al.* 2005). Prior to the arrival of Emerald Ash Borer (*Agrilus planipennis*, hereafter EAB) in Ohio, White Ash (*Fraxinus americana*) was among the five most common tree species with an estimated 3.8 billion individuals occurring in that state (Griffith *et al.* 1993). Ash trees play an important role in nutrient cycling in hardwood forests (Reiners and Reiners 1970). Their seeds, including those of the Blue Ash, provide important sources of food for wildlife such as squirrels, small rodents, Wild Turkeys (*Meleagris gallopavo*), quail and various songbirds (Ostfeld *et al.* 1997; Hulme 1998; MacGowan 2003; see dispersal below). The twigs and leaves of ash trees are eaten by White-tailed Deer (*Odocoileus virginianus*) and rodents (Waldron 2003).

The genus *Fraxinus* has 282 associated arthropod species (74 of which are at high to moderate risk; Gandhi and Herms 2010). Blue Ash appears to be unique among the five native species of ash in Ontario in that it is less preferred by EAB than Green Ash or White Ash (Tanis and McCullough 2012). Extirpation of ash trees because of EAB mortality over the next few decades is predicted to have cascading ecological impacts and alter ecosystem processes (Gandhi and Herms 2010).

Blue Ash is the most drought-resistant species within the genus (Farrar 1995). When the inner trunk bark of the Blue Ash is macerated in water and boiled it produces a blue dye, which was used by Aboriginal peoples (Farrar 1995). The wood of Blue Ash is hard and durable and has similar uses to the wood of White Ash, being used for furniture, tools and firewood (Waldron 2003).

DISTRIBUTION

Global Range

Blue Ash is found in the United States from Ohio to Wisconsin and south to northern Georgia and Arkansas (Figure 1). In Canada, populations exist only in southwestern Ontario in the counties of Elgin, Essex, Chatham-Kent, Lambton, and Middlesex.

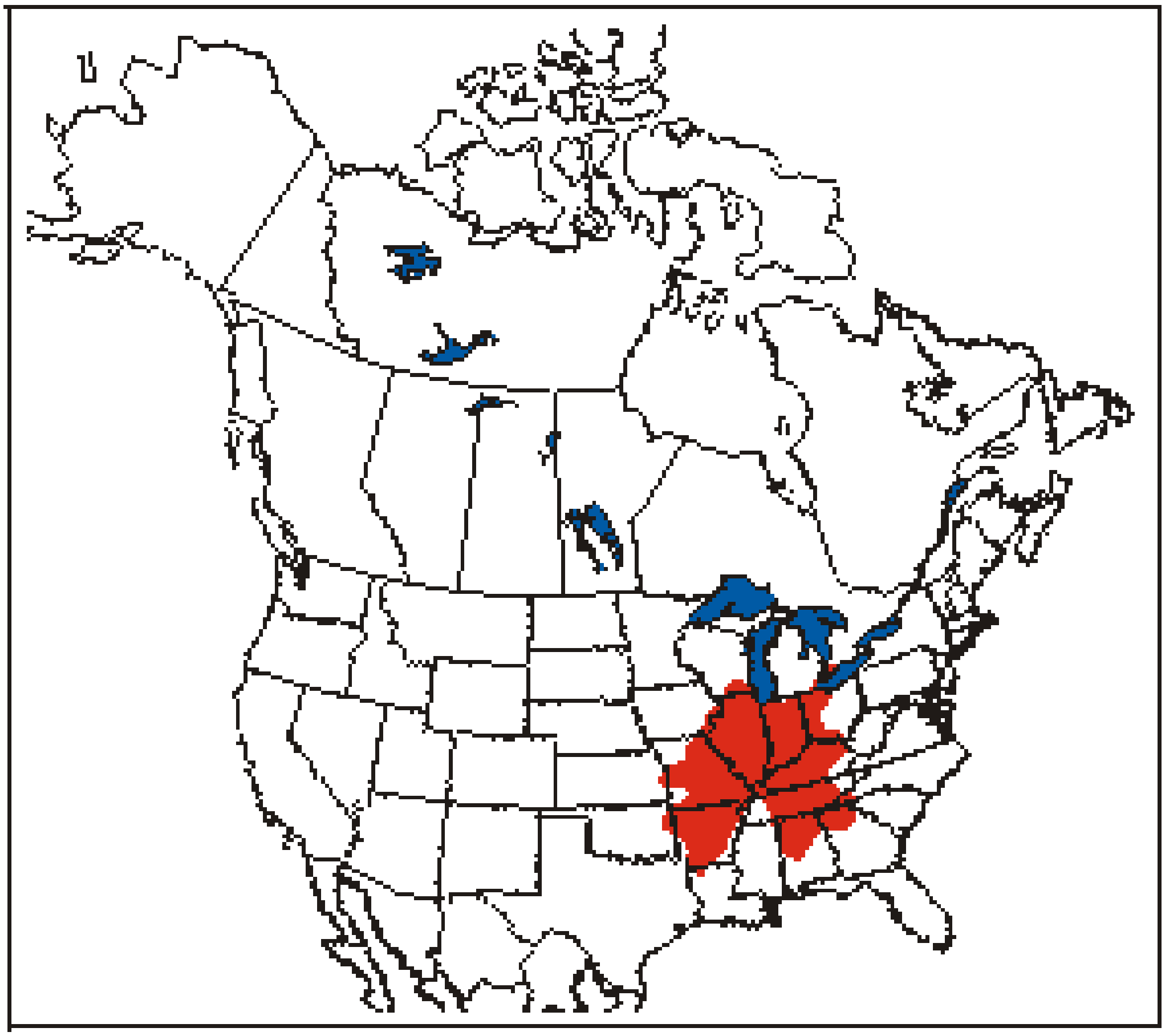

Figure 1. North American range of Blue Ash. (Source: Royal Ontario Museum: http://www.rom.on.ca/ontario/risk. php?doc_type=map&id=40).

Canadian Range

In Ontario, Blue Ash occurs at Point Pelee, Peche Island, the islands in Lake Erie, and valleys along the Thames River, Sydenham River, and Catfish Creek (Ambrose and Aboud 1983; White and Oldham 2000; Fig. 2). In 1983, Ambrose and Aboud reported 14 sites with Blue Ash within four regions of southwestern Ontario: the floodplains of the Thames River in Middlesex and Elgin Counties (as far north as Komoka); the floodplains of the St. Clair River in Lambton County; Point Pelee National Park and nearby islands of Lake Erie in Essex County; and a single small population in Elgin County near Lake Erie. Since then, 34 new sites have been identified, and White and Oldham (2000) recognized a total of 37 extant subpopulations through the amalgamation of nearby sites.

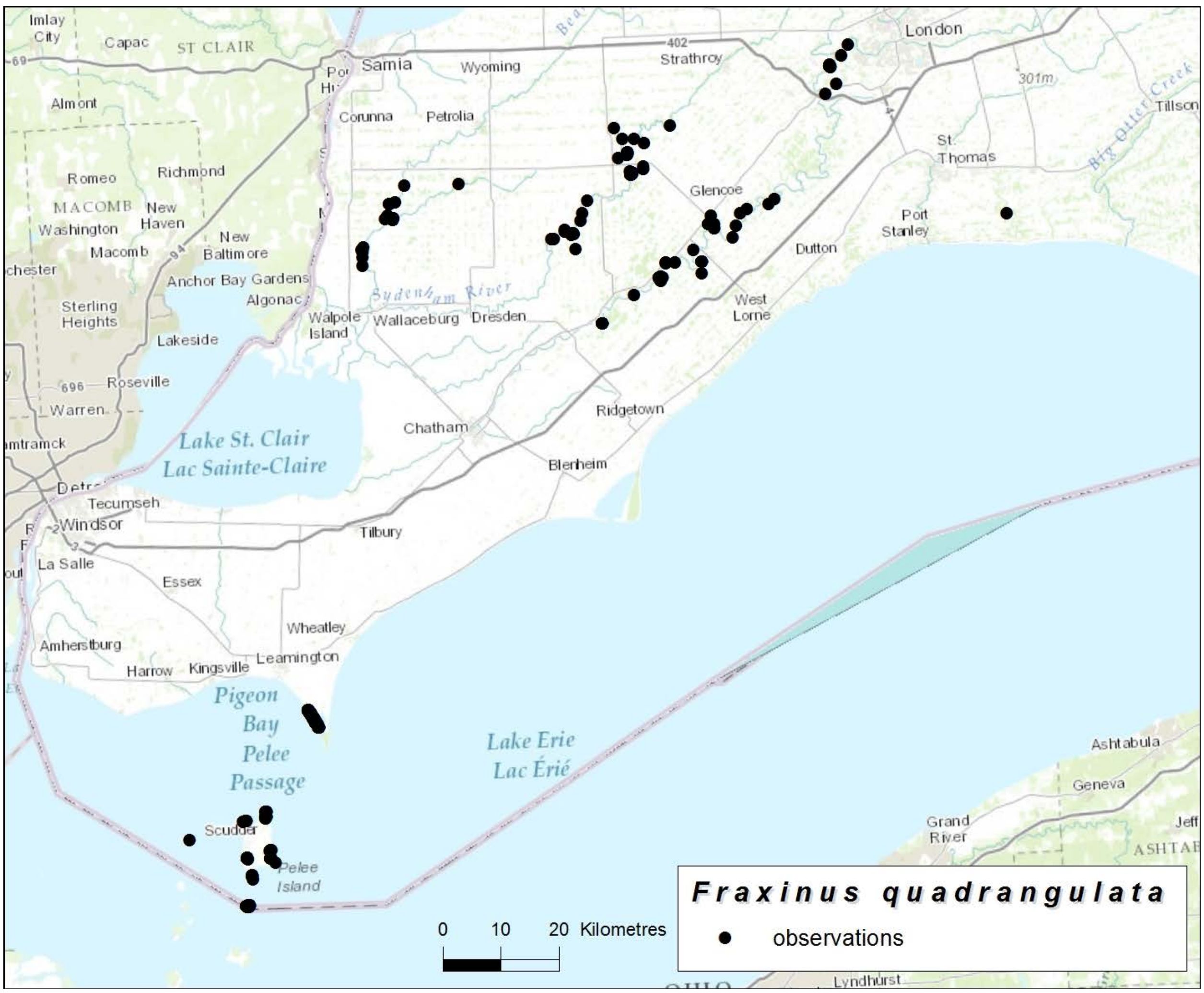

Figure 2. Approximate location of extant Blue Ash subpopulations in Ontario (map provided by Jenny Wu, COSEWIC Secretariat).

Blue Ash is sometimes planted in both urban and more natural settings. The potential inclusion of these individuals as part of the wildlife species and in the application of quantitative criteria was evaluated according to COSEWIC's Guidelines on Manipulated Populations (COSEWIC 2010). There are three instances of known manipulated populations of Blue Ash in Ontario in the Shetland Conservation Area (St. Clair Region Conservation Authority), at Sturgeon Creek (just outside Point Pelee National Park, Hynes 2002), and in the City of Windsor.

Blue Ash planted at the Shetland Conservation Area and at the administration centre at Sturgeon Creek just outside Point Pelee National Park are considered part of the wildlife species and included in the quantitative assessment following Guidelines 3 and 7 (COSEWIC 2010). These intra-limital sites are in proximity to natural occurrences, and were planted intentionally by the authorities managing Blue Ash conservation at each site. In addition, the trees at Sturgeon Creek were propagated from Blue Ash trees within the national park.

There are estimated to be 500 Blue Ash trees planted in the City of Windsor, most as street trees, although Blue Ash has also been planted at Windsor's Carolinian Arboretum. The trees at the arboretum are in more of a natural setting, but the purpose of planting was "so that visitors can enjoy the diversity of trees while they walk or cycle" (City of Windsor 2004). Planting of Blue Ash trees in Windsor began about 18 years ago (Paul Pratt, pers comm. 2013), but these trees are not in a natural setting and were not planted for the purpose of conservation (Guideline 2, COSEWIC 2010), and there are many barriers to natural reproduction. An outstanding question remains as to whether the Windsor trees should be considered extra-limital (Guideline 4, COSEWIC 2010). This determination rests on the status of trees on Peche Island, for which there is little available information. At this time, trees in Windsor are deemed excluded from the wildlife species (according to Guideline 2), and not considered in application of quantitative criteria, as there is no evidence that they would have a positive impact on the wildlife species. In fact, it is possible that these trees would serve as a reservoir for Emerald Ash Borer, and thus potentially negatively impact Blue Ash and other Ash species.

Extent of Occurrence and Area of Occupancy

The extent of occurrence for Blue Ash in Canada is estimated as 8884 km^2. The index of area of occupancy is 272 km^2.

Search Effort

Since the 2001 report, several surveys have been conducted for Blue Ash. These include surveys done in: 1) 2004 at Catfish Creek, Elgin County (Otis, pers. comm. 2013); 2) 2004, 2012, and 2013 of Kains Woods and Fanshawe forest by staff of the Upper Thames Region Conservation Authority (Quinlan, Gallagher, Williamson, pers. comm. 2013); 3) 2007 in Lambton County by the St. Clair Region Conservation Authority (Mills and Craig 2008); 4) 2006 in Point Pelee National Park by Gard Otis (Otis, pers. comm. 2012); 5) 2007 on Middle Island, Point Pelee National Park by Jalava (Jalava *et al.* 2008) and North-

South Environmental (2004) and a comprehensive survey in 2012 carried out by Parks Canada Agency (Dobbie, pers. comm. 2013). 6) 2012/2013 sample surveys done on Pelee Island, and the Sydenham and Thames rivers to estimate the proportion of trees infested by EAB (Kirk 2013).

University of Guelph and Catfish Creek Conservation Authority

As part of a study of Emerald Ash Borer, surveys for Blue Ash were carried out by the University of Guelph in Elgin, Middlesex/Lambton and Essex County. Surveys were conducted by Sally-Jo Gallant and Barbara Bleko in 2005 and Victoria Moran, Laura Robson, and Holly Dodds in 2006.

A complete inventory was done of Blue Ash trees at Point Pelee National Park between early May and the end of June in 2005 and 2006. Surveys were conducted by Sally-Jo Gallant and Barbara Bleko in 2005 and Victoria Moran, Laura Robson, and Holly Dodds in 2006. This inventory was distinct from the EMAN plots studied in 2009-2011 to monitor EAB.

Upper Thames Region Conservation Authority – Kains Woods and Fanshawe Forest

Visits to Fanshawe Conservation Area to inventory Blue Ash were carried out by staff of the Upper Thames Conservation Authority in October 2004, as well as September 2012 and September 2013.

St. Clair Region Conservation Authority – Sydenham River 2007-2008

Between September 2007 and 1st March 2008, St Clair Region Conservation Authority staff carried out surveys for six tree species including Blue Ash on 32 properties in 70 vegetation management units (totalling 700 ha; Mills and Craig 2008). This survey included mostly public lands owned by St. Clair Region Conservation Authority; some properties were included in the counties of Lambton and Middlesex and in the Municipality of Southwest Middlesex.

Jarmo Jalava and Parks Canada – Middle Island, Point Pelee National Park

Surveys were carried out of Blue Ash trees on Middle Island in 2007. However, this was not a systematic survey of Blue Ash and some trees were undoubtedly missed. A complete survey of Blue Ash trees on Middle Island was carried out in September by Point Pelee National Park staff with six people conducting the surveys over two days (96 person-hours). In addition tree health was assessed using the EMAN health classifications: 1 = Healthy (90% living); 2 = Moderate (51-89% living), 3 = Severely damaged (1-50% living); and 4 = Main stem dead with suckers; 5 = Dead, no suckers (Tammy Dobbie, pers. comm. 2013).

Kirk (2013) – surveys in 2012 and 2013 on the Thames and Sydenham Rivers and Pelee Island

Three people (John Ambrose, Paul O'Hara and Gerry Waldron) carried out surveys for Blue Ash on Pelee Island on three separate days in July 2012 (totalling 41 hours). One or two observers (Donald Craig and David Kirk) surveyed sites on the Sydenham and Thames Rivers in 2012 and 2013 totalling about 99 person-hours.

HABITAT

Habitat Requirements

Blue Ash occurs in rich bottomlands or well-drained sand, as well as floodplains of clay, fine sand, and silt, and shallow soil over dry limestone (Oldham and Brinker 2009, Strobl and Bland 2013). It tends to grow on the hill slopes, upper and lower terraces and floodplains of river valleys (see Bendix and Hupp 2000 for diagram).

Although Blue Ash will grow in a range of soil types, it grows best on moist, well-drained, rich alluvial soils (Ambrose and Aboud 1983). In Ontario, it grows in three distinctive forests and soil types: 1) nutrient rich floodplain forests along major river valleys; 2) shallow soils over limestone bedrock and 3) sandy, well-drained soils. Floodplain sites include those within the St. Clair and Thames River Watersheds, while the latter two habitats occur only on the islands and spits of western Lake Erie. Because of the close proximity of Lakes Erie and Huron, the climate is moderated by the lakes (Managhan *et al.* 1992), thus providing suitable growing conditions for Blue Ash.

It has intermediate shade tolerance and will grow in closed canopy conditions (Strobl and Bland 2013). However, for seedlings to regenerate natural disturbance is required to open up the canopy. In some situations, trees not exposed to sufficient sunlight may die (e.g., Mills and Craig 2008). The type of disturbance leading to canopy opening varies according to the forest types above. For example, in floodplains, fluctuations of water discharge create and maintain geomorphological processes and forms that influence riparian vegetation (Bendix and Hupp 2000). Floodplain sites and adjacent forest are also subject to natural disturbances such as windthrow, ice storms and insect infestations. In addition such sites are subject to anthropogenic disturbance like single tree selective logging. In contrast, fire is the most common natural disturbance in alvars and oak savannahs (Donald Kirk 1994, NCC 2008).

In the Sydenham River area (St. Clair Region Conservation Authority), Blue Ash grows in river and major creek valleys or in woodlots adjacent to those valleys (Mills and Craig 2008). Of the 21 natural sites occurring in watersheds in this region, the greatest number are in rolling uplands (7 sites), with the remaining ones in floodplains (3), floodplain ridges (1), ridges (1), slopes (3), gully slopes (3), levees (1), or parks (1). (Information was missing from one site in the Reid Conservation Area.) Blue Ash at these sites grows in several different Ecological Land Classification (ELC) groupings.

Along the Thames River (n = 15 sites), Blue Ash grows chiefly on the side slopes and floodplains of the main streams as well as major tributaries. The soils at these sites vary from silt loam to clay loam and occasionally clay. It is unusual to find Blue Ash trees growing more than a few metres back from the top of the valley bank (Donald Craig, pers. comm. 2012).

On Middle Island, Point Pelee National Park, Blue Ash grows mainly in the south-central and southeastern parts of the island in four vegetation types (Kamstra *et al.* 1995, North-South Environmental 2004). These include Hackberry forest (FODM 4-3 - one Blue Ash locality), Hackberry-Sugar Maple forest (FODM 7-5 - three Blue Ash locations), Hop-tree-Blue Ash-Chinquapin Oak forest (no ELC classification), and Dogwood-Sumac. The Hop-tree-Blue Ash-Chinquapin Oak forest has been invaded by Hackberry and was classified by North-South Environmental (2004) as Hackberry-Blue Ash-Common Hoptree forest.

At Stone Road Alvar (Pelee Island), Blue Ash grows on shrub alvar ecosite ALS1 (Shagbark Hickory-Prickly Ash Alvar Woodland), which includes species such as Chinquapin Oak (*Quercus muehlenbergii*), Climbing Prairie Rose (*Rosa setigera*), Gray-headed Coneflower (*Ratibida pinnata*), Common Prickly-Ash (*Zanthoxylum americanum*) and Shagbark Hickory (*Carya ovata*).

The second ecosite type where Blue Ash occurs at Stone Road Alvar is Shrub Alvar Ecosite ALS1b (Dogwood-Sumac Species Shrub Alliance); here associated species are Chinquapin Oak, Downy Arrowwood (*Viburnum rafinesquianum*), Downy Woodmint (*Blephilia ciliata*), Fragrant Sumac (*Rhus aromatica*), Long Hairy Chickweed (*Cerastium velutinum*), Nodding Onion (*Allium cernuum*), Shagbark Hickory, Silky Dogwood (*Cornus amomum*), Staghorn Sumac (*Rhus typhina*), Grey Dogwood (*Cornus racemosa*), and Whorled Milkweed (*Asclepias verticillata*).

Finally, Blue Ash occurs in the Dry Tallgrass Woodland Ecosite TPW1 a (Blue Ash-Chinquapin Oak Woodland Type) where associated species are Alum-root (*Heuchera americana*), Bottlebrush Grass (*Elymus hystrix*), Chinquapin Oak, Climbing Prairie Rose, Cut-leaved Conobea (*Leucospora multifida*), Davis's Sedge (*Carex davisii*), Elm leaved Goldenrod (*Solidago ulmifolia*), False Solomon's Seal (*Maianthemum racemosum* spp. *racemosum*), Long Hairy Chickweed, Hairy Tick-trefoil (*Desmodium canescens*), (Hairy Small-leaved Tick-trefoil) Leaf-cup *Polymnia canadensis*, Bearded Meadow-parsnip *Thaspium barbinode*, Nodding Onion, and Tall Thoroughwort *Eupatorium altissimum* (NCC 2008).

Habitat Trends

Historical and ongoing habitat loss, fragmentation and degradation are often considered the most significant causes of declines to species at risk in the Carolinian life zone (Venter *et al.* 2006, Kerr and Cihlar 2004), and this is possibly also true of Blue Ash. Over the last two centuries 94% of forest cover in southern Ontario has been lost, originally due to clearance for agriculture, and more recently for urban expansion (Larson *et al.* 1999). In counties where Blue Ash occurs, historical losses are more than 90% in Essex and Chatham-Kent counties, more than 85% in Lambton and Middlesex counties and more than 80% in Elgin County.

Recent estimates of overall forest cover in southern Ontario's Lake Erie-Lake Ontario Ecoregion (7E) are roughly 10-12% (Jalava *et al.* 2007, Crins *et al.* 2009). Although there are differences in methodology and resolution, some coarse estimates of changes in forest cover can be made by comparing estimates from the Blueprint for Ontario (2002) with the most recent estimates derived from SOLRIS (2013 aerial photography; Dan Kraus, pers. comm. 2013). The latter estimate includes coniferous, deciduous, unclassified forest, mixed forest, plantations, tallgrass woodland and treed sand barren and dune (but not swamp). For the district of Chatham (Ecodistrict 7E 1; Lee *et al.* 1998) the most recent estimate was 8,246 ha (compared to 12,007 ha in 1998). Similar estimates for St. Thomas (Ecodistrict 7E 2) indicated forest area as 99,145 ha for 2013 (133,586 ha in 1998). Finally, for Stratford South (Ecodistrict 7E 6,) forest cover was 16,511 ha for 2013 (20,757 ha in 1998). These numbers all suggest ongoing reductions in overall forest cover within the range of Blue Ash in Ontario.

Recent estimates of forest cover suggest higher cover moving from southwest to northeast within the range of Blue Ash. The lowest area of forest is reported in Essex county (54.9 km^2, or 3.1% of land area), followed by Lambton (337.6 km^2, 11.2%), Middlesex (432.5 km^2, 13.0%), and Elgin (292.8 km^2, 15.5%; Carolinian Coalition 2008). Note that parts of Essex County, such as Pelee Island, have fairly extensive forest cover (41.47 km^2 or 20.5% of the area), with 3.5% of this forest being interior forest, and 10.2% riparian (Rob Davies and Roger Palmini, pers. comm. 2013). Similarly, although small in area (0.43 km^2), Lake Erie islands have 78.5% forest cover, with 7.7% being interior forest.

In addition to regional trends, specific information is available for changes in forest cover on Middle Island attributed to the destructive activities of nesting Double-crested Cormorants, documented using aerial photographs (Hebert *et al.* 2005) and satellite imagery (Duffe 2006). In the western part of the island first colonized by cormorants, forest cover declined from 92.3% in 1995 to 40.4% in 2001 (51.9% decline). Blue Ash occurs in one area within this forest type. Other areas where Blue Ash occurs have not been as severely impacted.

These patterns of loss have produced a highly fragmented forested landscape in the range of Blue Ash in Ontario; most woodlots are less than 8 ha and are isolated from neighbouring woodlots (Ontario Nature 2007). For example, watershed report cards demonstrate that most watersheds and sub-watersheds within the St. Clair Region Conservation Authority Region, as well as the Upper Thames, Lower Thames and Essex Region Conservation Authorities, have forest cover well below the level recommended by Environment Canada in (Table 3). In addition the grades for forest interior conditions indicate that remaining woodland patches are often of low quality (Ontario Nature 2007). Many fragments are long and linear containing no interior forest (forest that is at least 100 m from an edge) and often isolated from other patches by large distances (Ontario Nature 2007).

Table 1. Summary of Blue Ash sites surveyed in 2012/2013 in southern Ontario (sites are listed geographically from northeast to southwest).

EO ID	Region and Site	Ownership	Date	Observer	#trees (% surveyed)	# mature trees (%)
Upper Thames River						
	1. Fanshawe Conservation Area	Lower Thames Valley CA	1-Oct-04 and 9-Sept-13	B. Gallagher, C. Quinlan	20-30	c 10 (33-50)
11364	2. Kains Woods	Lower Thames Valley CA	9-Sept-13	B. Williamson	93 (100)	35-40
Thames River						
21577	3. Komoka Provincial Park (WMU 91A)	Province of Ontario	25-Oct-12	G. Waldron, S. Hughes	26 (100)	19 (42.2)
	4. 1 km from Newbiggin Creek Simpson Road, Thames River (WMU 92B)	Private	19-Oct-12	D. Craig, D. Kirk	49	16 (32.7)
	5. Crinan Creek, Lot 20 (WMU 92B)	Private	27-Sep-12	D. Craig	16	2 (12.5)
11359	6. 0.5 km east of Wardsville (WMU 92B)	Private		D. Craig	25	11 (44.0)
	7. Thames River 3.5 km SW of Wardsville (Newport Forest; WMU 92B)	Thames Talbot Land Trust	18-Oct-2012 and 26-28 Mar-13	D. Craig	221	96 (43.4)
	8. Wardsville Woods (WMU 92B)	Thames Talbot Land Trust	16-Sept-12	D. Craig	13	4 (40.0)
2406	9. Moravian IR (WMU 93A)	First Nations	27-Nov-12	D. Craig, D. Jacobs	41	0 (0)
Sydenham River						
	10. Close to south of Courtright line site in Mosa twp (WMU 93A)	Private	13-Nov-12	D. Craig	2	2 (100.0)
11365	11. McAlpine Tract (WMU 92B)	St. Clair Region CA	27-Sep-12	T. Payne, D. Craig	176 (0.5^2)	58 (33.0)

EO ID	Region and Site	Ownership	Date	Observer	#trees (% surveyed)	# mature trees (%)
2423	12. A.W. Campbell Conservation Area (WMU 93A and 92B)	St. Clair Region CA	27-Sep-12	T. Payne, D. Craig	29 (2.6)	20 (69.0)
	13. East side of Sydenham about 0.5 km E of Alvinston (Gardiner Trail, Lot 20; WMU 93A)	Private landowner	4-Oct-12	D. Craig	10	7 (70.0)
	14. Haggerty Creek, Shetland Kentucky Coffee Tree Woods (WMU 93A)	Private landowner	19-Oct-12	D. Craig, D. Kirk	5 (100)	4 (80.0)
	15. Shetland Conservation Area (WMU 93A)	St. Clair Region CA	19-Oct-12	D. Craig, D. Kirk	6 (100)	4 (66.7)
	16. Bear Creek 7.5 km sw of Brigden Post Office, south side of creek (WMU 93A)	Private	30-Aug-12	G. Waldron, S. Hughes	9	3 (33.3)
2422	17. Duthill Woodlot (McKeough Dam) (WMU 93A)	St. Clair Region CA	19-Oct-12	D. Craig, D. Kirk	65 (8.6)	56 (86.2)
	18. Black Creek 1.5 km SE of Wilkesport Woodlot (McKeough Floodway Property # 83; WMU 93A)	St. Clair Region CA	19-Oct-12	D. Craig, D. Kirk	21 (7.4)	15 (71.4)
Point Pelee National Park (WMU 94A)						
2417	19. Point Pelee National Park of Canada	Parks Canada	May-July 2005, 2006 (2006 reported)	G. Otis, S.J. Gallant, B. Bleko, V. Moran, L. Robson, H. Dodds	476[1]	77 (16.2)
Pelee Island (WMU 95)						
2413	20. Stone Road Alvar	Nature Conservancy/Ontario Nature/Township of Pelee	25-Jul-12	J. Ambrose, G. Waldron, P. O’Hara	56	38 (67.9)
2418	21. Lighthouse Point	Pelee Island	25-Jul-12	J. Ambrose, G. Waldron, P. O’Hara	75	54 (72.0)
2411	22. Fish Point	Ontario Parks	25-Jul-12	J. Ambrose, G. Waldron, P. O’Hara	21	15 (71.4)
	23. Red Cedar Savannah (B-Ivey E-W road)	Private	24-Jul-12	J. Ambrose, G. Waldron, P. O’Hara	29	24 (82.8)
2419	24. Sheridan Point	Pelee Island	24-Jul-12	J. Ambrose, G. Waldron, P. O’Hara	71	32 (45.1)

EO ID	Region and Site	Ownership	Date	Observer	#trees (% surveyed)	# mature trees (%)
Others (WMU 94A)						
2414	25. Middle Island	Parks Canada	27-Sep-07	H. Brown, V. Minelga, J. Keitel, K. Leclair, S. McCanny, K. Scott, R. Windsor (Thorndyke)	231	106 (45.9)
	26. City of Windsor	City of Windsor		B. Roesel	500 (excluded)	500 (100)

[1]Note that surveys were carried out in Point Pelee National Park in 2005 and 2006 and the total number of trees measured was 2323. However, many small trees < 2 cm dbh were measured (866 in 2006). 894 trees were measured at the base of stems and not dbh as they were too small. 499 trees were 2-10 cm dbh (saplings). To make these data comparable with other surveys only trees >2 cm dbh are included.

[2] For the St. Clair Region Conservation Authority sites the trees surveyed in 2012 are shown as a percentage of those counted by Mills and Craig (2008). Many of the trees recorded by Mills and Craig (2008) were saplings and seedlings and the 2012 surveys focused on larger-sized trees.

Table 2. Description of Blue Ash sites surveyed for Emerald Ash Borer in 2012/2013 in southern Ontario (sites are listed geographically from northeast to southwest).

EO ID	Region and Site	Description	Soil type	Associated tree species	#Blue Ash trees with EAB	EAB presence in other ash trees
Upper Thames River						
	1. Fanshawe Conservation Area	South facing slope	n/a	AL, Hk, Or	0	0
11364	2. Kains Woods	60 m from River Thames	Sandy loam	Aw, Bd, Be, Hb, Iw, Ms, Or	0	Aw
Thames River						
21577	3. Komoka Provincial Park	Natural levee S bank Thames River		AL, Be, Cw, Bd, Mm, Mb, Ob,	0	Ab, Ag, Aw
	4. 1 km from Newbiggin Creek Simpson Road, Thames River	Gully bank	Clay-loam	Aw, Be, Hb, Hs, Iw, Mh, Or	0	0
	5. Crinan Creek, Lot 20	Gully incised into clay plain	Clay	Bd, Ew, Er, Osw, Wb	0	One or two Ag, Aw
11359	6. 0.5 km east of Wardsville	Top of slope	Clay-loam	Hk, Ms, Or, Ow, Wb	0	Aw
	7. Thames River 3.5 km SW of Wardsville (Newport Forest)	Gully in clay plain	Clay-loam	Aw, Bd, Er, Hs, Iw, Mb, Och	7 (14.3)	Ag, Aw
	8. Wardsville Woods	Valley bank	Clay-loam	Aw, Bd, Er, Ew, Hs, Ir, Mb, Ms, Ob	0	
2406	9. Moravian IR	Gully slope	Sand over clay	Aw, Bd, Hk, Ms, Wb	0	

EO ID	Region and Site	Description	Soil type	Associated tree species	#Blue Ash trees with EAB	EAB presence in other ash trees
Sydenham River						
	10. Close to south of Courtright line site in Mosa twp	Steep valley bank	Clay-loam	Aw, Iw, Ms	0	
11365	11. McAlpine Tract	Slope-gully site	Clay	Bd, Er, Mb, Ms, Ob, Wb	11 (6.3%)	
2423	12. A.W. Campbell Conservation Area	Gently sloping to rolling	Clay to clay-loam	Be,Hb, Iw, Ms,	0	
	13. East side of Sydenham about 0.5 km E of Alvinston (Gardiner Trail, Lot 20)	Floodplain	Silt-loam	Aw, Er, Ew, Hk	0	
	14. Haggerty Creek, Shetland Kentucky Coffee Tree Woods	Creek valley bank	Loam	Ag, Aw, Bd, Er, Hb, Mb, Ms	0	Ag, Aw
	15. Shetland Conservation Area (planted)	Floodplain			0	
	16. Bear Creek 7.5 km sw of Brigden Post Office, south side of creek	River valley incised into clay plain	Clay	Ag, Aw	0	Ag, Aw
2422	17. Duthill Woodlot (McKeough Dam)	Floodplain	Silt/clay	Ag, Aw, Bd, Hb, Iw, Ms, Or, Wb	11 (16.9)	Ag, Aw
	18. Black Creek 1.5 km SE of Wilkesport Woodlot (McKeough Floodway Property # 83)	Valley bank	Clay loam	Aw, Be, Bd, Er, Hk, Hs, Or, Ow, Wb	7 (33.3)	
Point Pelee National Park						
2417	19. Point Pelee National Park of Canada	Sand spit	Sand		9 (13%) (n=67[1])	Ag, Aw
Pelee Island						
2413	20. Stone Road Alvar	Alvar savannah	Limestone	Hs, Och,	4 (7.1)	
2418	21. Lighthouse Point	Alvar savannah	Limestone	Hk, Hs, Och	3 (4.0)	
2411	22. Fish Point	Sand spit	Sand	Ag, Aw, Hk, Ms	1 (4.8)	
	23. Red Cedar Savannah (B-Ivey E-W road)	Alvar savannah	Limestone	Cr, Hk	10 (34.5)	
2419	24. Sheridan Point	Alvar/quarry edge	Limestone	Hk, Ht, Kk,	4 (5.6)	
Others						
2414	25. Middle Island	Island	Limestone	Ag, Bd, Hk, Kk, Ms, Och and Hop-tree, Iw, Och	0	

EO ID	Region and Site	Description	Soil type	Associated tree species	#Blue Ash trees with EAB	EAB presence in other ash trees
	26. City of Windsor	Urban			3 (0.6)[2]	

[1] Note that only the 67 trees surveyed in the EMAN plots were examined for EAB. 572 trees > 2 cm dbh were measured at PPNP.
[2] Precise numbers of trees infested by EAB in the City of Windsor is unknown but believed to be 'several' (Roesel, pers. comm. 2013).

Key to tree species acronyms:
AL – All ash species
Ag – Green Ash (or Red Ash)
Aw – White Ash
Ar – Red Ash
Bd – Basswood
Be – American Beech
Cw – Eastern White Cedar
Er – Red Elm
Ew – White Elm
Hb – Bitternut Hickory
Hk - Hackberry
Hs – Shagbark Hickory
Ht – Hawthorn (Downy)
Ir – Ironwood
Kk – Kentucky Coffee-tree
Mb – Black Maple
Mm – Manitoba Maple
Ms – Sugar Maple
Ob – Burr Oak
Och – Chinquapin Oak
Ow – White Oak
Wb - Black Walnut

Table 3. Results of Blue Ash surveys conducted by the St. Clair Region Conservation Authority in 2007 (Mills and Craig 2008). Summarized for each site.

Region and Site	#trees	# mature trees (% > 10 cm dbh)	# saplings and seedlings
McKeough Dam (Unit 1, 2, 11)	754	123 (16.3)	631 (83.7)
Property # 82	6	0	6 (100)
Property # 83	284	37 (13.0)	247 (87.0)
Property # 91	124	1 (0.8)	123 (99.2)
Reid Conservation Area	519	37 (7.1)	482 (92.9)
McAlpine Tract	36,253	161 (0.4)	36,092 (99.6)
A.W. Campbell	1,146	33 (2.9)	1,113 (97.1)
Planted sites			
McKeough Dam	1		1 (100)
Shetland CA	7	4 (57.1)	3 (42.9)
Lorne C. Henderson CA	1		1 (100)
Strathroy CA	3		3 (100)
Wawanosh CA	2		2 (100)

Table 4. Forest cover from watershed report cards for watersheds where Blue Ash occurs.

Watershed or subwatershed	Letter grade - % forest	Letter grade - % forest interior	Letter grade - % forest riparian
Upper Thames River (overall)	D – 11.3	F – 1.4	C – 31.4
Komoka Creek sub-watershed (*Komoka Provincial Park*)	C – 21.1 (2007) C – 19.5 (2012)	D – 3.2 (2007) F – 2.3 (2012)	ND 44.0 (B)

Watershed or subwatershed	Letter grade - % forest	Letter grade - % forest interior	Letter grade - % forest riparian
Lower Thames River watershed (overall) *(Newport Forest, Moravian IR, Crinan Creek (#5), East of Wardsville (#6), Newbigging Creek at Simpson Rd))*	D – 10.0	ND	ND
Chatham-Kent	4.9	ND	ND
St. Clair Region watershed (overall)	D – 11.5 (2008)	D – 1.8 (2008)	ND
Lower North Sydenham ()	D – 9.4 (2008)	F – 1.1 (2008)	ND
Lower East Sydenham (*Dutton*, *McKeough Dam, McKeough Property 83*)	D – 5.9 (2008)	F – 0.4 (2008)	ND
Middle East Sydenham River (*Haggerty Creek, Shetland, Shetland CA, A. W. Campbell Conservation Area, McAlpine tract, East of Alvinston (#8), and south of Courtright Line (#11)*	C – 14.5 (2008)	D – 2.3 (2008)	ND
Lower Bear Creek (*Bear Creek*) #15	C – 14.7 (2008)	D – 2.4 (2008)	ND
Essex Region (overall)	D – 5.7 (2012)	F – 0.55 (2012)	F – 8.3 (2012)
Lake Erie watershed (*Pelee Island, Point Pelee National Park*)	B (2006) C (2012)	C (2006) D (2012)	ND ND
Detroit River watershed (*Windsor*)	B (2006) C – 6.1 (2012)	C (2006) D – 0.6 (2012)	ND 9.7

While historically sites containing Blue Ash may have been naturally fragmented because of its habitat preferences, it is likely that the species was more widespread prior to European settlement. There is no doubt that the woodlots in which Blue Ash occurs are currently fragmented, at least spatially if not functionally. Subpopulations of tree species that occur in such remnants can suffer from reduced gene flow through isolation (Hewitt and Kellman 2002, 2004), but many processes can affect metacommunity structure, including environmental gradients, dispersal and biological interactions (Logue *et al.* 2011, Moritz *et al.* 2013). As a result, the impacts of spatial fragmentation are not easily predicted. For example, recent work in Europe demonstrates that despite occurring in highly fragmented landscapes, ash trees (European Ash, *Fraxinus excelsior*) maintain their genetic diversity (Bacles *et al.* 2005), perhaps because dispersal was mediated in open deforested landscapes and could occur for up to 10s of kilometres (Lowe *et al.* 2005). This indicates that it is possible for Blue Ash to maintain genetic diversity despite occurring in highly fragmented landscapes. However, contrary to these findings, research in the Long Point Region of southern Ontario suggests that wind-dispersed tree species are negatively influenced by fragmentation (Hewitt and Kellman 2002).

While there is no direct evidence of genetic degradation, there is substantial evidence for ecological degradation of forest fragments (Kramer *et al.* 2008). Fragment degradation occurs through edge effects – including increased isolation and other effects on microclimate such as drying of soils, as well as impacts from neighbouring land uses. The extent to which these influences affect Blue Ash is unknown. Certainly, Blue Ash often occurs as a seed tree along the edge of woodlots bordering agricultural fields, and edges may provide suitable conditions for regeneration. Adjacent land uses, which could include pesticide use, may have deleterious effects (Boutin and Jobin 1998; Harper *et al.* 2005) but these are unknown. More intensive farming practices adjacent to woodlots can increase the abundance of grassy-type plants, which are often invasive species and weedy in nature. Conversely, adjacent to less intensively farmed fields species characteristic of the maple-tree association were found (Boutin and Jobin 1998). Generally speaking, more disturbed woodlots in southern Ontario have higher abundance of graminoids and invasive plant species (Burke and Nol 1998; Hynes 2002). It is possible that such woodlots and/or those adjacent to more intensively farmed fields may be more favourable for rodent numbers because of their grassy nature and thus be inimical to Blue Ash regeneration. The effect of invasive species on Blue Ash regeneration is unknown.

In general, the effects of habitat fragmentation are expected to include: (1) loss of habitat, (2) reduced fragment size, and (3) increased spatial isolation of remnant fragments. Small habitat fragments contain small populations, which are more vulnerable to extinction due to environmental and demographic stochasticity (Fahrig 2003). The COSEWIC definition of fragmentation (COSEWIC 2013) is that a taxon is considered severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are smaller than would be required to support a viable population and separated from other patches by a large distance. Empirical evidence to support this definition is lacking for Blue Ash, as for many species at risk in Canada. Nonetheless, it is safe to assume that extremely rare species are likely to fall within this definition (Fraser, pers. comm. 2013).

Most woodlots in southern Ontario are selectively logged for timber, either by private landowners or Conservation Authorities (Burke and Nol 1998). For example, the St. Clair Region Conservation Authority has conducted timber harvests at properties where Blue Ash occurs. While selective logging can provide conditions for Blue Ash regeneration, certain types of logging (e.g., high-grading or clear-cutting) are likely to be detrimental as they lead to greater graminoid cover or increase invasive species which could reduce seedling establishment (Mills and Craig 2008; Craig, pers. comm. 2013).

Most Blue Ash sites occur on private land and have little legal protection other than bylaws, which in many municipalities inhibit clearance of woodlots. However, in Chatham-Kent, attempts to establish a new conservation bylaw probably resulted in extensive forest clearance in 2012/2013 because of fears by landowners that such activities would be restricted (Jalava, pers. comm. 2013). It is not known whether any sites containing Blue Ash were cleared. However, the conservation bylaw was not passed and woodland conservation will now be addressed through stewardship. The only known Blue Ash site that occurs in Chatham-Kent is the Moravian Indian Reserve, but other unknown sites may exist in this area.

It is important to point out that the sites where Blue Ash grows are often low priority for forest clearance since they often are floodplains, have slopes too steep for cultivation or are close to rivers with riparian forest buffers (Craig, pers. comm. 2012).

BIOLOGY

Relatively little information is available on the biology of the Blue Ash and some differences occur among sources. The main sources of information on the Blue Ash used here include Waldron (2003), Mills and Craig (2008), Strobl and Bland (2013), and Prasad *et al.* (2007-ongoing).

Life Cycle and Reproduction

Unlike other ash species, Blue Ash usually typically has perfect flowers, and few single sex trees exist (Strobl and Bland 2013). Flowering occurs in April and May, prior to leaf-out and pollination occurs by wind. Fruits are single-seeded samaras (keys). Seed crops are produced every 3-4 years in late fall. In Ontario, seeds have been recorded on trees over about 10-17 cm dbh (Mills and Craig 2008; Craig, pers. comm. 2013). Seed banking occurs for one or more years and cold stratification is required for germination (Strobl and Bland 2013). Other than suckers sprouting from cut stumps, there is no evidence of clonal spread. In Ontario, seedlings and saplings occurred at 10 of the 26 sites, with the largest numbers at Point Pelee National Park, the McAlpine Tract, Newport Forest and Sheridan Point. In 2007, Mills and Craig (2008) estimated 36,000 seedlings and saplings at the McAlpine Tract. Longevity estimates vary according to source. Strobl and Bland (2013) report the maximum longevity as 300 years (typically 200 years) and the age of maturity (fruiting age) as 25 years. However, the USDA Tree atlas reports maximum longevity as 150 years (Prasad *et al.* 2007-ongoing).

Generation time of Blue Ash has not previously been estimated. Assuming that trees over 10cm DBH are capable of reproducing, it is possible to use the size structure of the population to estimate generation time. Cores of dead Blue Ash trees from the Sydenham River watershed (McKeough floodway) suggested that maximum growth rates could be up to 1 cm per year. However, growth rates vary according to site conditions; on Lake Erie Islands trees can grow as slowly as 2 mm per year (Waldron 2003). Using averaged growth rates from three seedlings and three dead trees, Mills and Craig (2008) estimated the age of trees of a range of size classes, from 10 cm dbh (28 years), 24 cm dbh (68 years), 38 cm dbh (108 years), to 50 cm dbh (142 years). Ages of Blue Ash trees can also be estimated from growth correction factors for other ash species. It should be cautioned that tree growth rates are influenced by many factors such as water availability, climate, soils, root stress, competition, and plant vigour. No growth rate correction factor is available for Blue Ash but rates for White and Green Ash are 5 and 4 respectively (Missouri Department of Conservation 2013). An average of these values can be used (4.5) but Blue Ash grows more slowly than these species and a correction factor of 3 may be more appropriate (similar to Shumard Oak *Quercus shumardii* or Kentucky Coffee-tree *Gymnocladus dioicus*).

To calculate generation time, the average age of mature trees was estimated using the sample of mature trees (> 10 cm dbh) surveyed in 2012/2013 and growth correction factors obtained from the Sydenham River (Mills and Craig 2008) and growth correction factors based on growth rates in other ash tree species. Average age varied from 51 years from growth rates calculated by Mills and Craig (2008) to 70 years using a growth correction factor of 3 (similar to Shumard Oak and Kentucky Coffee-tree), and 105 years using a growth correction factor of 4.5 (average of White Ash and Green Ash).

Field surveys as part of this assessment indicated that of the mature trees (n = 1213), 31 (2.6%) were 49-61 cm dbh and nine trees (0.7%) were 62 cm or more in diameter. The largest individual trees were at Point Pelee National Park (87.9 cm dbh), in the Newport Forest (84 cm dbh, 21 m height), the McAlpine Tract (80 cm dbh, 23 m height) and Fish Point (76 cm dbh, 25 m height). Only 77 trees (8.2%, n = 939) reached a height of 18 m (60 feet) and 14 trees (1.5%) were 25 m or more (80 feet).

Physiology and Adaptability

Although Blue Ash grows best in well-drained, moist and alkaline soils, it will grow in a wide range of soil types. For example, sites with Blue Ash on Pelee Island are extremely dry and some are on sand spits. By contrast, some sites in floodplains are sometimes waterlogged, or at least imperfectly drained. The Blue Ash also has a high tolerance for drought and is considered the most drought-resistant of North American ash species (Waldron 2003).

Dispersal and Migration

Ash fruits are winged and thus adapted to being dispersed primarily by wind. Blue Ash fruits can disperse from 10 m (Strobl and Bland 2013) to 200 m from the parental tree (Prasad *et al.* 2007-ongoing). Recent studies of European Ash in fragmented landscapes in Scotland indicate that dispersal can occur over tens of kilometres (Bacles *et al.* 2010).

Ash seeds can also potentially disperse over much longer distances by water (Strobl and Bland 2013). For example, it is very likely that at many river valley sites Blue Ash keys would be carried to water and thus colonize stream banks downstream of the seed trees. The fact that seeds of other wind-dispersed tree species (American Beech, *Fagus grandifolia* and Eastern Hemlock,*Tsuga canadensis*) can be transported across the Great Lakes (Davis *et al.* 1986) suggests that this might also be possible for Blue Ash seeds.

Some birds may also contribute to seed dispersal over longer distances. Several bird species consume ash tree seeds (see **Interspecific Interaction**)**.** Seeds may survive intact in the intestinal tracts of Wood Duck (*Aix sponsa*), and possibly in other game species (Green, pers. comm. 2013; Whelan, pers. comm. 2013). Ridley (1930) mentions that intestines of Wood Duck contained White Ash seeds and that this species will often wander far from water to feed on upland seeds, so it seems plausible that Blue Ash seeds could be eaten and dispersed by Wood Ducks (Whelan, pers. comm. 2013). Small mammals may also contribute to seed dispersal.

Interspecific Interactions

Seed Consumers

Blue Ash seed consumers include Wood Duck, quail species (within Blue Ash range in Ontario, only the non-native Grey Partridge *Perdix perdix*), Northern Bobwhite (*Colinus virginianus*), Wild Turkey, Northern Cardinal (*Cardinalis cardinalis*), Purple Finch (*Carpodacus purpereus*), Evening Grosbeak (*Coccothraustes vespertinus*), Pine Grosbeak (*Pinicola enucleator*), and Cedar Waxwing (*Bombycilla cedrorum*; Martin *et al.* 2011). Songbirds are thought to destroy seeds during consumption (i.e., in the process of consumption and pre-consumption handling – Whelan, pers. comm. 2013), but some seeds may survive in the intestinal tracts of ducks and other game birds (Green, pers. comm. 2013; Whelan, pers. comm. 2013).

Various mammals also consume ash seeds and those that occur within the range of the Blue Ash in Ontario include American Beaver (*Castor canadensis*), White-footed Mouse (*Peromyscus leucopus*) and Fox Squirrel (*Sciurus niger* – Martin *et al.* 2011 refer to the Western Fox Squirrel as consuming ash seeds). Mammals that eat ash foliage such as White-tailed Deer could also consume seeds of Blue Ash. Some of these mammal species could occasionally disperse seeds.

White-tailed Deer

White-tailed Deer numbers have increased over the last several decades in southwestern Ontario. Abundant White-tailed Deer populations have had significant impacts on forest ecosystems throughout northeastern North America (Russell *et al.* 2001; Rooney and Waller 2003). These include browsing of woody and herbaceous species as well as cascading ecosystem effects such as selective browsing. Deer also disperse seeds in their feces (endozoochory; Myers *et al.* 2004), including both native species and many exotic species (Myers *et al.* 2004). While there is little information available on the direct impact of White-tailed deer on Blue Ash, trends in deer abundance in southern Ontario, and the general impact of deer on forest communities can serve to indicate the potential for negative impacts on Blue Ash.

The main information on deer numbers in southern Ontario comes from harvest statistics compiled by the Ontario Ministry of Natural Resources. Deer in southwestern Ontario do not yard to the extent that they do in other areas, so yard counts are not possible (McCauley, pers. comm. 2014). Harvest statistics come from hunter returns and include estimates of the number of deer killed (bucks, does and fawns), as well as the number of hunters, the number of hours hunted and the number of deer seen. Many biases exist with harvest statistics and they may be poor predictors of deer density in areas where hunting is restricted (e.g., in fragmented forests) and thus of limited value for supporting site-level management decisions (Koh *et al.* 2010). Moreover, the spatial coverage of the available data is coarse and is not sufficiently spatially explicit to give a clear indication of potential correlations between deer numbers and browsing intensity. This must be borne in mind when using data from harvesting to assess the potential impacts of deer browsing on Blue Ash recruitment.

Harvest statistics on deer were obtained from the Aylmer Office of the Ontario Ministry of Natural Resources. These data comprise the number of deer harvested and seen in each Wildlife Management Unit (WMU; see Figure 3). The number of deer killed was multiplied by a factor of 4 based on the finding that 18-25% of the population is usually harvested each year (McCauley pers. comm. 2014). To account for differences in search effort, the number of deer seen was divided by the number of hours or days hunters reported that they spent hunting.

Results showed some differences in trends between the Wildlife Sub-management Units within the range of Blue Ash (Figs. 4-8). For example, in WMU 93A, deer numbers increased over the 20-year period from 1992 to 2012 (Fig. 7; linear regressions, not shown, were highly significant). This WMU corresponds to many of the sites where Blue Ash occurs along the Sydenham River. Few of these sites had regeneration (seedlings and saplings). Other Blue Ash sites along the Thames River (e.g., Wardsville Woods) occur in WMU 92B where deer numbers are apparently fluctuating (no clear trend – see Fig. 5). At some of these sites Blue Ash regeneration was noted (Newbiggins Creek) in response to forest disturbance. However, extensive regeneration occurred at the McAlpine Tract (also WMU 92B), but the age structure was very skewed, with few large trees. The other site where extensive regeneration was found was Komoka Provincial Park (Newport Forest; Waldron, pers. comm. 2012). This site occurs close to London in a WMU (91A), which has declining deer numbers according to harvest and sighting data (Figs 4 and 6). However, the park management plan (Ontario Parks 2010) refers to overabundant deer populations and that there may be a need to reduce deer numbers. No deer occur on Pelee Island or Middle Island (Wildlife sub-management Unit 95) and extensive Blue Ash regeneration was found at several of the sites surveyed there during fieldwork in 2012-2013 (Kirk 2013).

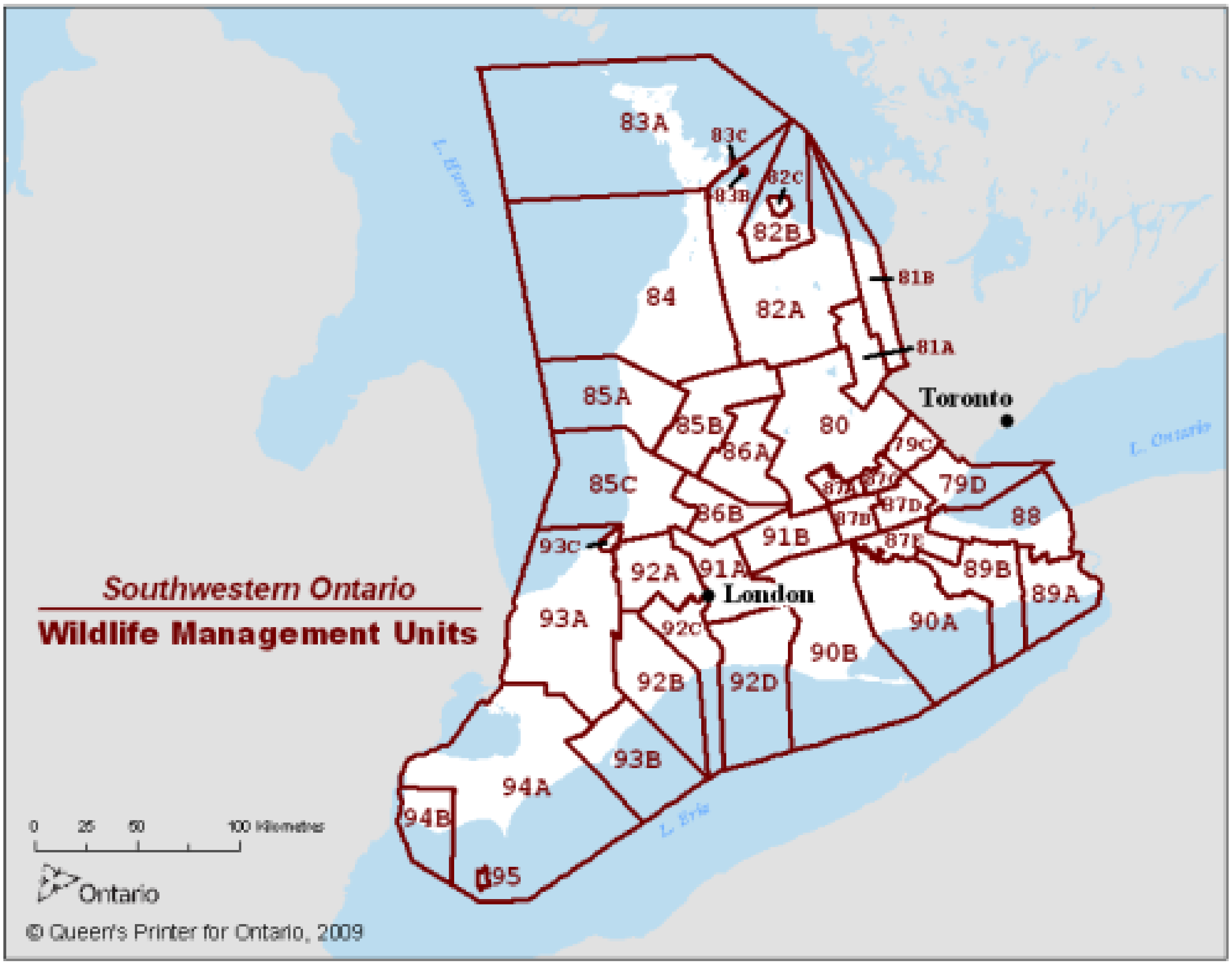

Figure 3. Wildlife Management Units of southwestern Ontario (Source: Ontario Ministry of Natural Resources).

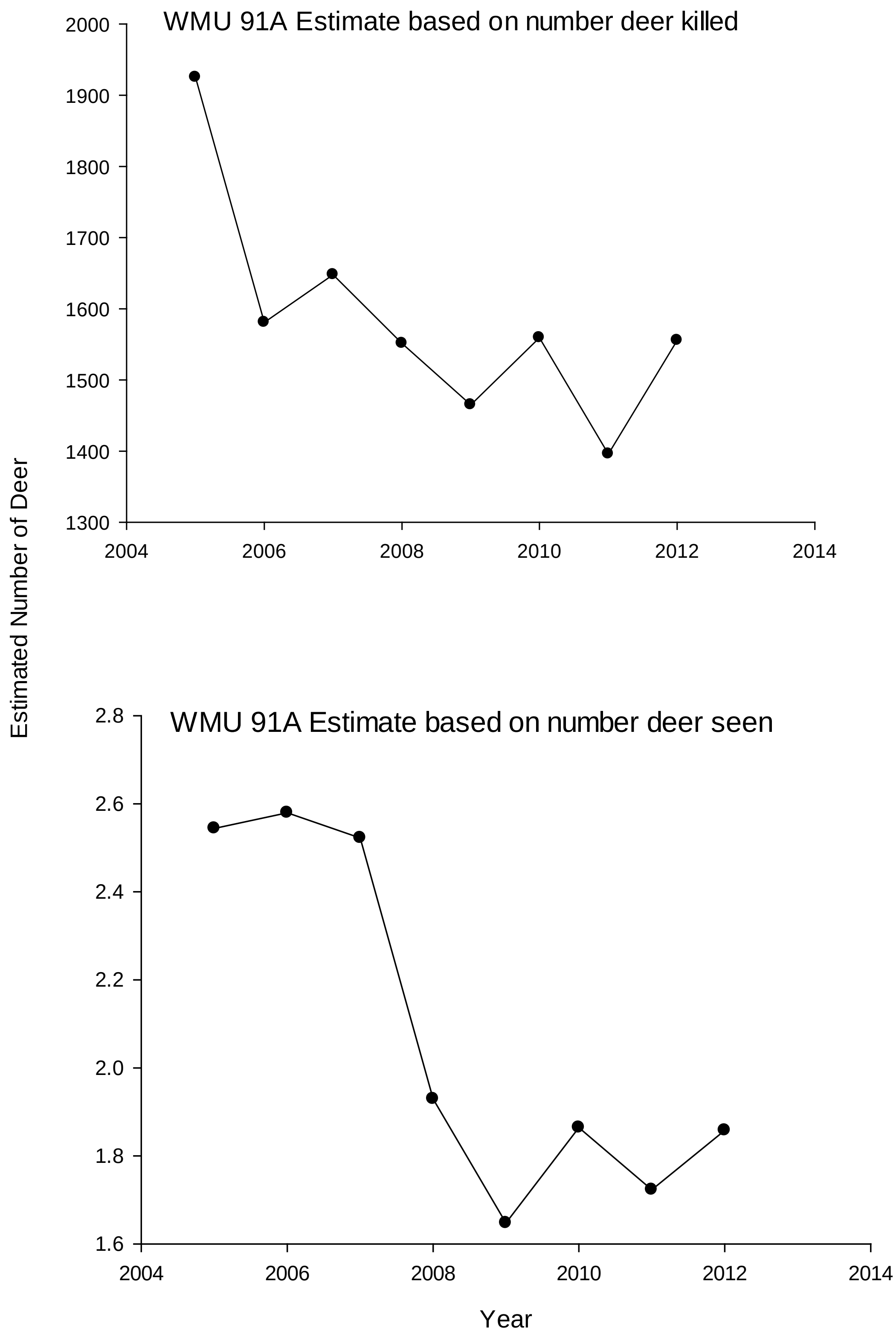

Figure 4. Estimate of deer numbers in Wildlife Sub-Management Unit 91A (London).

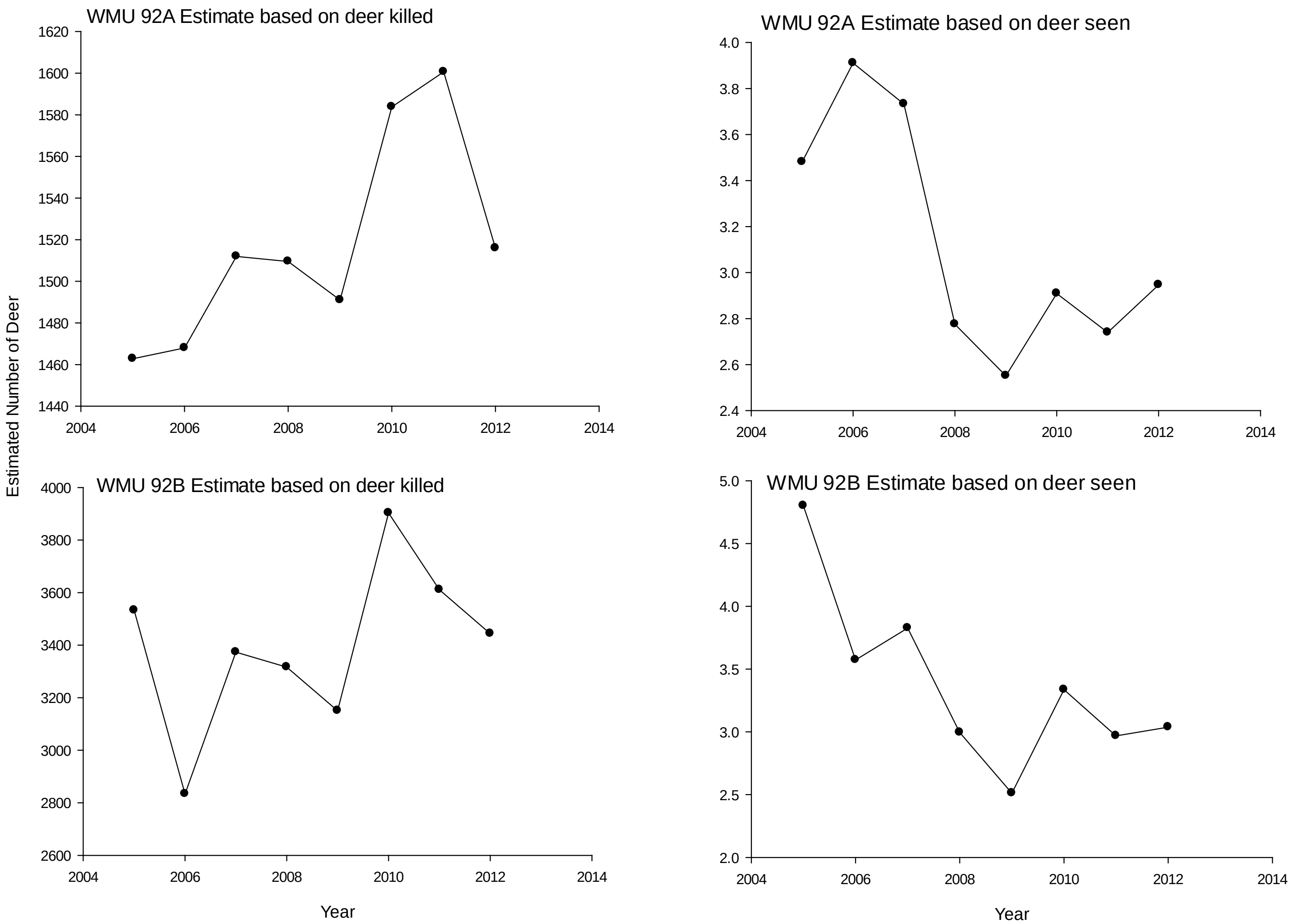

Figure 5. Estimate of deer numbers in Wildlife Sub-Management Units 92A and 92B (some Sydenham River sites).

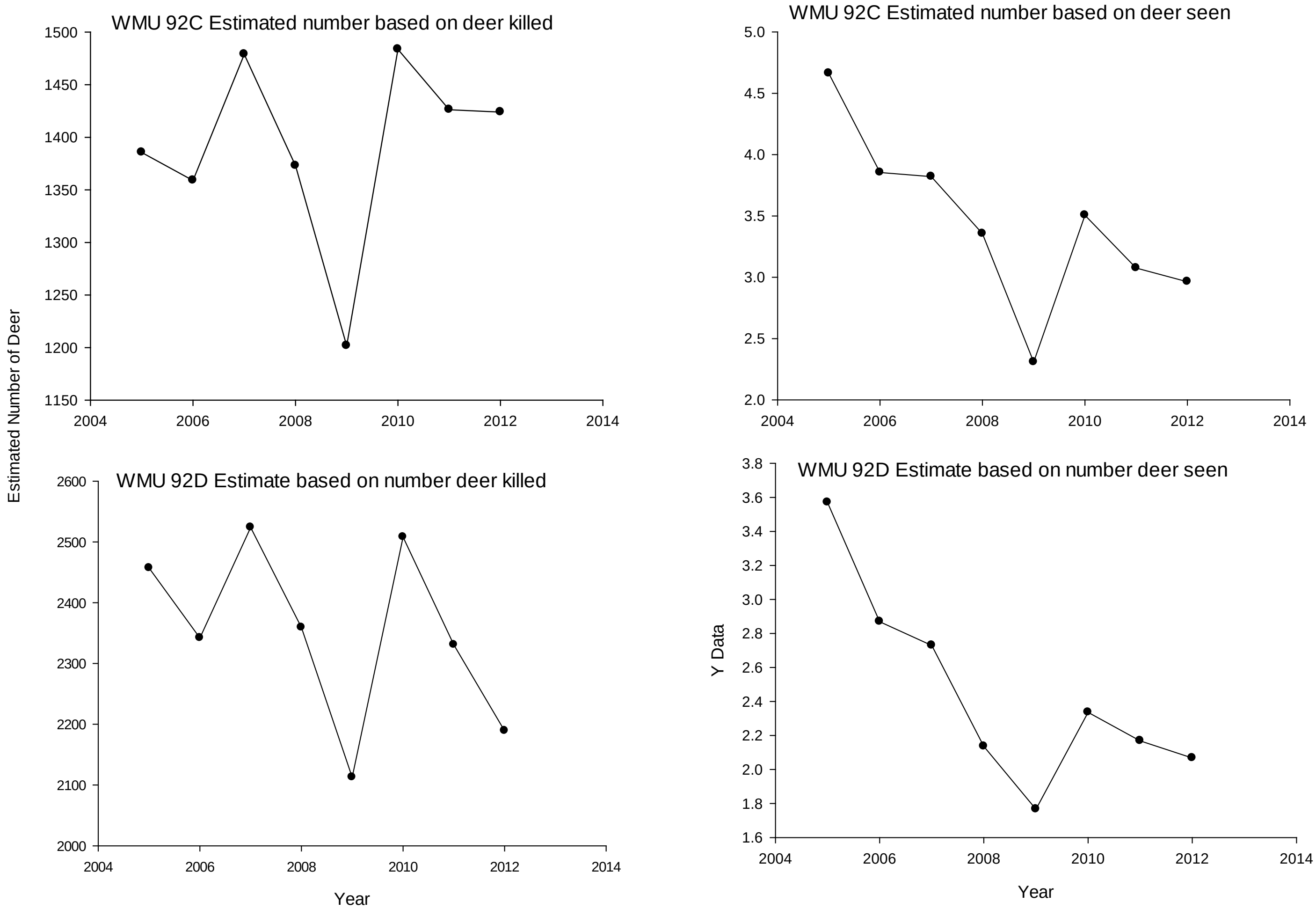

Figure 6. Estimate of deer numbers in Wildlife Sub-Management Units 92C and 92D (Catfish Creek)

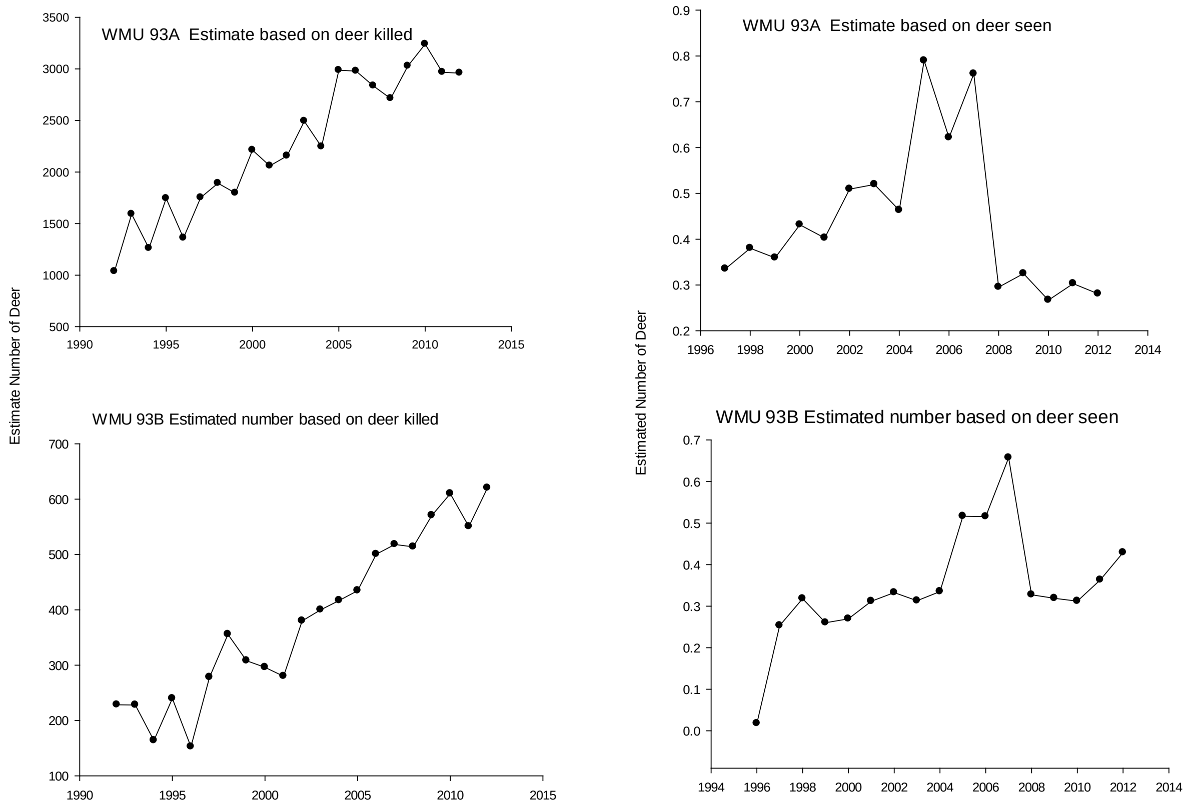

Figure 7. Estimate of deer numbers in Wildlife Sub-Management Units 93A (Sydenham River) and 93B (Thames River).

Figure 8. Estimate of deer numbers in Wildlife Sub-Management Unit 94A (South of Wallaceburg, Chatham, Point Pelee National Park)

The Ontario population of White-tailed Deer is estimated at around 400,000 and believed by OMNR and others to be much too high (OMNR 2014). High deer numbers are attributable to a number of factors including the extirpation of predators (e.g., Gray Wolf, *Canis lupus*, Cougar, *Puma concolor*), generally milder winters, a decline in hunting pressure and agricultural expansion (Côté *et al.* 2004). For example, in southern Ontario there has been a shift from growing tobacco crops to row crops such as corn and soybean, as well as wheat (OMAFRA 2014), which provide more food sources for deer.

In an ecosystem that already has high levels of fragmentation and habitat loss, deer can cause reductions in habitat quality in woodland fragments, by altering the trajectory of forest development and preventing regeneration of woody species and browsing species such as *Trillium* (Koh *et al.* 2010). Despite reductions in deer populations, however, forest recovery can take many decades and may require other management actions to accelerate the process (Tanentzap *et al.* 2011, 2012).

Surprisingly little published information exists on the significance of deer browsing on Blue Ash. As a starting point, information on deer browsing pressure at Blue Ash sites (beyond estimating the abundance of deer, as above) would be helpful. Indirect indicators of browsing pressure could be used at Blue Ash sites. For example, Koh *et al.* (2010) found a strong relationship between the mean heights of *Trillium* and deer browsing pressure in southern Ontario.

It is well known that deer browse ash twigs and leaves (Waldron 2003), but it is not clear whether Blue Ash constitutes preferred browse or what the impacts of deer browsing are on Blue Ash seedling and sapling survival. In Kentucky, there is evidence that Blue Ash is strongly preferred by White-tailed Deer (Julian Campbell, pers. comm. 2014, Campbell in preparation). In a Bluegrass Woodland restoration project where 3-5 year old (1-1.5 m tall) Blue Ash saplings were planted in an old hayfield, Campbell (in preparation) found a 28% mortality rate after four years. Spatial variation was found in survival and growth rates in relation to distance from a road. Lower survival was found for plants with initial heights of 1-1.5 m, but this trend was weak. Also most breakage caused by deer occurred at 0.3-1 m above ground, suggesting that seedling mortality may occur early on.

Making a case for the impacts of deer on Blue Ash regeneration and population dynamics in Ontario is challenging without more information. Specifically, more data are required on browsing pressure and impacts on seedling survival using long-term study plots and exclosures, as well as the landscape context of sites (including alternative food supplies). Blue Ash regenerates well in open canopy conditions and thus requires disturbance such as windfalls (selective tree harvest can also simulate natural disturbance, as well as death of other ash tree species individuals from EAB). For example, at the Kains Woods site, although deer are abundant heavy shade by oak prevents any Blue Ash regeneration (Enright pers. comm. 2013; Quinlan pers. comm. 2013). The interaction between deer browsing and disturbance and impacts on Blue Ash would require a long-term study.

Emerald Ash Borer (EAB)

Blue Ash is host to a large number of insect species and historically has generally been disease-free. It is, however, attacked by Emerald Ash Borer, an invasive alien beetle from Asia. First detected in Detroit, Michigan in 2002 and Windsor, Ontario in the same year, the spread of the Emerald Ash Borer (EAB) has been extremely rapid. It is now found in two Canadian provinces (Ontario and Québec) and 21 states including Ohio (2003), Indiana (2004), Illinois and Maryland (2006), Pennsylvania and West Virginia (2007), Wisconsin, Missouri and Virginia (2008), Minnesota, New York, Kentucky (2009), Iowa and Tennessee (2010), Connecticut, Kansas and Massachusetts (2012), New Hampshire, North Carolina, Georgia and Colorado (2013). Tens of millions of ash trees have been killed (OMNR 2013). Beetles were discovered in southern Ontario in the summer of 2002, and have now spread northeastwards in Ontario and into Québec.

The life cycle of this beetle is typically one year, though evidence suggests that some individuals may take two years to reach maturity (OMNR 2013). From late May through July, female EABs lay single eggs in bark crevices. The eggs hatch after about two days and there are four larval stages (instars) that begin feeding on the phloem and outer sapwood, growing in size as they bore deeper into the sapwood. Following feeding over the summer, the larvae overwinter from October or November and pupate in late April to June. The freshly formed adults stay in their pupal chambers for 8-15 days and then bore through the bark leaving the characteristic D-exit holes (the typically ‘D’ shaped exit holes left by emerging EAB adults). Emergence begins in mid- to late May and peaks in mid-June. The adults then live about one month, with mating taking place 7-10 days following emergence. Females mate on multiple occasions and lay an average of 70 eggs (and up to 250 eggs; OMNR 2013).

Damage to ash trees is caused by EAB larvae, which girdle the stem and branches. Tree mortality is caused by larvae feeding in the phloem and vascular cambium. EAB can be difficult to detect for the first 3-4 years of infestation. In addition to the D-exit holes, external signs of EAB include S-shaped or serpentine galleries (tunnels and chambers present under the bark), and increased woodpecker activity. Epicormic shoots (shoots that emerge on the trunk or from along a tree branch) and leaf dieback are symptomatic of EAB being present in the tree. Some other insect species can also leave D-exits but the combination of D-exit holes and other signs and symptoms are distinctive of EAB. Various woodpecker species feed on the larvae and perhaps emerging adults under the bark of infested Blue Ash.

Even though the EAB can only move short distances (up to 10 km, based on laboratory experiments), their rapid spread is attributed to long-distance “jump” dispersal where a species moves extremely large distances through human transportation of saplings or contaminated firewood (Muirhead *et al.* 2006). Initially it was thought that Emerald Ash Borer would impact only some species of ash and that Blue Ash was completely resistant. However, Muirhead *et al.* (2006) indicated that all ash species were affected including Red Ash, White Ash, Black Ash (*Fraxinus nigra*), Pumpkin Ash (*Fraxinus profunda*) and the Blue Ash.

The most recent research suggests that Blue Ash shows resistance to EAB in most areas and is not as susceptible as most other ash species. Tanis (2013) found that adult EAB caged on Blue Ash trees had lower survival than when they were caged on other ash species (Black Ash and Green Ash); they also consumed less leaf area. She also found that while Black and Green Ash were heavily colonized by EAB larvae, Blue Ash and Manchurian Ash were rarely colonized. Blue Ash possesses characteristics not found in other native North American ash species that may confer resistance to EAB (Tanis 2013). In particular, phenolic compounds present in both Blue Ash and Manchurian Ash (*Fraxinus mandshurica* which co-evolved with EAB in Asia, and shows also resistance) were not detectable in Green Ash (Tanis 2013). Moreover, the phloem of both Blue Ash and Manchurian Ash has a continuous layer of sclerenchymatous cells, whereas in Green Ash this layer is not continuous (Tanis 2013).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Prior to conducting fieldwork in 2012 and 2013, all observation records of Blue Ash (n = 46, or amalgamated n=37 element occurrences) were obtained from the Ontario Natural Heritage Information Centre (NHIC), together with 19 sites submitted by the St. Clair Region Conservation Authority in 2001. All Element Occurrences and observations were mapped, with specific trees or clusters of trees located using Google Earth (Google Earth 2013). It was impractical to survey all sites; instead the largest subpopulations, as well as some incidental sites with few trees, were prioritized. For the most part, sites that were omitted contained few trees and in some cases access to them was difficult. For Catfish Creek, the survey was undertaken too late in the season, so was not included.

As part of this report, most fieldwork was carried out in the summer and fall of 2012 and one survey (Newport Forest) in the spring of 2013. The goals of this survey were fourfold: 1) to assess the distribution and abundance of Blue Ash at as many known sites as possible (with some additional new sites); 2) assess the health and status of as many Blue Ash trees at these sites as possible, particularly in relation to signs of EAB; 3) inventory the size structure at sites (tree diameters and heights); and 4) record site characteristics including soil type and tree species composition.

All primary observers had some experience with Blue Ash and EAB and were already familiar with all sites. Because of time constraints and logistical considerations, not all trees within stands could be surveyed. This was especially true at the McAlpine, Duthill Woodlot # 1 (McKeough Dam), 1 km from Newbiggin Creek Simpson Road, Thames River and Thames River 3.5 km SW of Wardsville (Newport Forest) sites, as well as sites on Pelee Island. For example, some stands contained several hundred trees (e.g., McAlpine Tract). In some areas, the number of trees was estimated rather than counted by observers (e.g., for the City of Windsor, Roesel, pers. comm. 2012; Kains Woods, Gallagher, pers. comm. 2013; and Fanshawe Conservation Area, Williamson, pers. comm. 2013).

Trees smaller than 2.5 cm dbh were considered seedlings, trees from 2.5-10 cm dbh were considered saplings and trees ≥ 10 cm dbh were considered mature individuals. For some sites, the abundance of saplings and seedlings that were not measured (usually smaller than 2-4 cm dbh) was estimated visually. Where several stems were present from the same root stock, the total basal area was combined to calculate a diameter equivalent. Mature trees were assigned to diameter size classes (10-24 cm dbh; 25-36 cm dbh; >37-48 cm dbh; >49-61 cm dbh; and 62+ cm dbh).

Signs of EAB activity were recorded following de Groot *et al.* (2006). Signs include the characteristic S-shaped or Z-shaped (serpentine) galleries created by EAB larvae between the bark and the sapwood, the D-shaped exit holes (3.5-4 mm diameter), feeding notches on leaves, and evidence of animals feeding on larvae (woodpecker holes or squirrel damage to bark). Old galleries occur in trees that have been infested for more than one year and can be recognized by the rounded ridges on their sides (callus tissue) caused by new tree growth. Care must be taken in identifying EAB, as there are other beetle species that make D-holes (de Groot *et al.* 2006).

Symptoms of EAB damage to trees, including the presence of epicormic shoots, cracks in the bark over galleries, yellowing of leaves, and crown dieback were also recorded. It should be noted that some of these symptoms can occur in response to other stressors. For example, epicormic shoots can be produced when a neighbouring windfall tree damages a tree. Leaf dieback can also be caused by other stresses, including drought. Leaf dieback was assessed for most sites; however, some sites were surveyed too late in the season to assess this adequately as most of their leaves had already fallen.

Abundance

Of 1,806 trees counted at the 25 sites surveyed (excluding 500 trees in the City of Windsor), 708 (39%) were ≥10 cm dbh and are considered mature individuals. It is important to reiterate that the surveys in 2012/2013 were not a complete inventory of all trees at all sites (though at many sites all trees were counted). At least 22 known sites were not surveyed in 2012, and Blue Ash is probably present in many other unsurveyed woodlots in the watersheds of the Sydenham and Thames rivers. This is illustrated by comparing the number of trees counted in the St. Clair Region Conservation Authority area with the survey done by Mills and Craig (2008; Table 1 vs Table 3). White and Oldham (2000) documented 37 sites where the species occurred and estimated that the population was around or less than 1,000 mature trees. While it is not currently possible to accurately assess the total Canadian population of Blue Ash, the total may not reach 2,500 and is unlikely to exceed 10,000 mature individuals.

Fluctuations and Trends

No information is available on fluctuations and trends in the Blue Ash population in Ontario. Search effort has not been standardized and recent surveys suggest that Blue Ash is much more common than previously believed. Without complete surveys, or visits to the same sampling area over time it is impossible to compare trends temporally.

Rescue Effect

The closest trees to apparently natural Blue Ash in Canada are on South Bass Island in Ohio (Herms, pers. comm. 2013). These trees are about 12 km from those at the southern tip of Pelee Island in Ontario. It is entirely feasible that seeds from Blue Ash trees could be dispersed in Lake Erie and that there is interchange between these two populations. The closest Blue Ash to the excluded trees in Windsor, Ontario are specimens in Detroit, Michigan, USA, which are only 5.4 km away (Google Earth 2013).

THREATS AND LIMITING FACTORS

The IUCN threats calculator was completed for Blue Ash to help clarify the scope, severity and impact of threats. This calculator uses the threat classification of Salafsky *et al.* (2009), and focuses on ongoing threats. However, the impact of ongoing threats may be heightened in the context of limiting factors and previous threats that have been abated or have ceased. For Blue Ash in southern Ontario, as with many species in this region, habitat loss associated with past expansion of human population has resulted in fragmentation and loss of habitat (see **Habitat Trends**), which should be considered when evaluating the anticipated impact of threats.

Threats

Empirical information quantifying the scope and severity of threats is lacking in most instances. An attempt has been made to identify data uncertainties and potential impacts for each threat, but at present the impact of threats is estimated based mainly on indirect evidence and inference. This process has resulted in the identification of two threats, browsing by White-tailed Deer and effects of Emerald Ash Borer that are likely to impact the entire range of Blue Ash in Canada, and an additional set of threats with limited scope or unknown severity. Beyond stating that the first two are of greater impact than the remainder, it is not possible to rank these threats.

<u>Problematic Native Species: Impacts of White-tailed Deer (High-low Impact)</u>

Grazing by large numbers of White-tailed Deer has had detrimental impacts on plant diversity in southern Ontario and has resulted in local extirpation of native plant species, as well as reduced shrub cover and increased cover of graminoids (Hynes 2002; Hynes *et al.* 2002; Koh *et al.* 2010). Deer grazing has also changed forest structural characteristics including by reducing tree density and creating more forest openings (Koh *et al.* 1996, 1999; Larson and Waldron 2000). However, the impact of deer browsing on Blue Ash is unknown. High densities of deer in some areas could reduce Blue Ash regeneration and prevent recruitment.

Generally it is likely that sites with Blue Ash that occur in WMUs that have high populations of deer with increasing trends over time would potentially be most impacted by deer browsing (see **Interspecific Interactions**). Although harvest data may be of some use in determining deer numbers, there was evidence that some sites that occur in WMUs with high densities of deer still had extensive regeneration (e.g., McAlpine Tract), and more direct measures of browsing pressure are needed to substantiate indirect inferences.

At sites where there are many mature trees and there is closed canopy cover it would be predicted that White-tailed Deer would have less impact than at sites where there is natural disturbance or logging to open up the canopy and create conditions for regeneration. It is also likely that deer browsing of Blue Ash would be accentuated in areas where deer congregate. The landscape context of Blue Ash sites may also determine the extent of deer browsing. For example, browsing may be more intense in areas that lack preferred browse species.

Invasive Species: Emerald Ash Borer (Medium-Low Impact)

Evidence is conflicting on the degree of threat posed by EAB to Blue Ash. Early reports suggested that Blue Ash would not be attacked by EAB, but more recent evidence suggests that it is susceptible but less preferred than Green or White Ash (Tanis and McCullough 2012; see **Interspecific Interactions**). During fieldwork conducted as part of this assessment, signs of EAB were found at 45.8% (11 out of 26) of sites surveyed. However, the number of Blue Ash trees infested with EAB was typically small and overall represented 3.7% of trees surveyed for EAB (70 out of 1,889 trees). The percentage of trees infested with EAB varied from 0.6% in Windsor to 34.5% at the Red Cedar Savannah on Pelee Island (Table 2). Other sites showing symptoms of EAB infestation were at the McKeough Property 83 (33% of surveyed trees) and the McAlpine Tract (16.5%). Eight trees (0.42% of total; 11.4% of infested trees) had apparently been killed by EAB. It is possible that the incidence of EAB was underestimated because incomplete surveys were done at some sites (which may have inadvertently biased estimates of EAB incidence in some way), and detailed inspections of individual trees was not done at all sites (e.g., planted trees in Windsor). If the Blue Ash trees in Windsor are excluded from the total then the percentage of trees infested by EAB increases to 5%, and percentage killed increases to 0.58%.

In all cases the mean dbh of trees with signs of EAB was smaller than the overall mean dbh at the site (Table 2). The smaller size of infested trees may be partly an artifact of detectability, as larger trees have thicker bark making galleries harder to detect; as well, galleries or D-exit holes may be located higher up and therefore less visible. By contrast, in smaller diameter trees the bark is thinner and cracks and sunken areas are more readily seen (Donald Craig, pers. comm. 2013 and D. Kirk, personal observations).

A second finding during surveys was that Blue Ash trees infested by EAB were generally stressed or damaged. This was the case at the McKeough Dam and Newport Forest. Although EAB will colonize and kill healthy ash trees (Cappaert *et al.* 2005; Poland and McCullough 2006), generally it preferentially colonizes stressed trees (McCullough *et al.* 2009a, b).

It might be expected that the intensity of infestation in Blue Ash would be elevated closest to the original source of EAB (i.e., Detroit or Windsor). However, apparently this was not the case. For example, only a small percentage of trees in Windsor appear to be affected by EAB (‘several’ trees out of 500; Roesel, pers. comm. 2013). Although initially Blue Ash trees in Windsor did not appear susceptible (infestations were occurring in 2003), by 2008-2009 at least some trees were infested (Roesel, pers. comm. 2009), and by 2013 several trees had EAB (Roesel, pers. comm. 2013). These trees are atypical in that they were planted in an urban setting, and so the microclimate around trees is very different from what it would be in semi-natural or wild populations. For example, they probably have much more sun exposure, as well as maintenance from the City of Windsor (they also have stressors such as pollution, soil compaction and urban heat island effects).

Pelee Island is also close to the original areas of invasion. However, until fieldwork in 2012, no signs of damage from EAB were observed on Blue Ash trees on Pelee Island, despite extensive infestations of Black Ash and other ash species (including Pumpkin Ash; Ambrose, pers. comm. 2012). Of the areas surveyed in 2012/2013, Pelee Island had the highest proportion of sites with EAB.

Generally, it appears that compared to other native ash species, Blue Ash is resistant to infestations from EAB and many or most trees recover or survive attacks (see **Interspecific interactions**). However, this may vary spatially and could depend on the presence of other ash tree species and numbers of EAB in the area. The one tree where callus was visible around the galleries at the McKeough Dam site on the Sydenham River indicated that the tree had been infested four years earlier (in 2008) when live ash trees of other species were abundant. Similarly at Newport forest on the Thames River, some of the galleries were 2-3 years old and the presence of callus tissue indicated that the trees were infested 2-3 years ago when the White and Green Ash in the area were alive. This suggests that at some sites, Blue Ash is attacked by EAB before all individuals of other ash tree species are killed (Craig, pers. comm. 2012). At other sites EAB only seems to moves on to the Blue Ash when White and Green Ash are mostly dead (Tanis and McCullough 2012) such as in Delaware County, Ohio (Knight, pers. comm. 2012).

The extent to which Blue Ash can survive attacks by EAB is a critical issue. In most cases, trees remain healthy despite infestations. For example, at two sites in Michigan, Tanis (2013) found that survival rates for Blue Ash were 63% and 71%, respectively, whereas survival rates for White Ash were 16% at one site, and 0% at the other site. In parts of Ohio, Blue Ash is still surviving despite the fact that White and Green Ash are all dead (Knight, pers. comm. 2012). At other sites in western Ohio, all Blue Ash trees have been killed (Miller, pers. comm. 2012). Although the precise number of trees involved is not available, one site was a small woodlot owned by the village of Bluffton where there were 25 'fair-sized' Blue Ash trees. Other sites at Gibsonburg and on limestone islands included approximately 300-600 stems per ha.

In conclusion, at this time, there is a great deal of uncertainty about the impact that EAB is likely to have on Blue Ash in Ontario. Levels of mortality have been low over the first decade of EAB invasion, but may change, especially once White and Green Ash have been reduced or eliminated. To date, the most susceptible Blue Ash appear to be those that are already stressed by other factors (e.g., damage from windfall, ice-storms, lightning strikes, or those shaded by competitors). Monitoring of trees is therefore important to determine the severity of impact of EAB on Blue Ash in Ontario. In the worst case scenario, assuming that EAB becomes pervasive and infests most or all Blue Ash trees, current levels of mortality (11.4% of infested trees) could be taken to represent the overall level of susceptibility of Blue Ash to EAB, but it must be emphasized that it is not known whether infestation levels will rise (i.e. because of declines in favoured hosts), decline (because overall levels of EAB may decline with declines of other Ash species), or remain roughly the same.

In addition to direct effects of EAB, Blue Ash may be impacted by attempts to manage the spread of EAB, by selectively removing any Ash trees that show signs of EAB. In the case of Blue Ash, given that many trees appear to survive infestation, this practice should be strongly discouraged.

While it is possible that Blue Ash could also have been cut down by authorities during management efforts to control the spread of EAB generally this seems unlikely (Gard Otis, pers. comm. 2013). Cutting and burning of infected ash trees by the CFIA occurred in 2002 and 2003, at the leading edge of EAB infestation. However, despite continued extensions of quarantine areas, by the end of 2012, EAB had been found in 27 Ontario counties and seven areas in Québec, and the CFIA has since altered its approach to EAB management since aggressive containment was not effective (CFIA 2013). Two main strategies are currently being used to attempt to contain EAB. The first is to restrict the movement of wood from infected forests (all tree species) within a consolidated large area around the Highways 400, 401, 416 and 417 in Ontario and Highways 15, 20, 40 and 50 in Québec. Secondly, two parasitic wasps (*Tetrastichus planipennisi*, and *Spathius agrili*) have been approved for release by Natural Resources Canada (CFIA 2013). These wasps originate from northern China and their effectiveness in controlling EAB has been evaluated in Michigan (Duan *et al.* 2013). Recently it has been found that EAB is susceptible to a native parasitic wasp species (*Atanycolus cappaerti*) in the lake states and perhaps elsewhere (Rieske-Kinney, pers. comm. 2014). A wasp of the same genus (*Atanycolus* spp.) has also been identified attacking EAB in Kentucky (Rieske-Kinney, pers. comm. 2014).

Other Problematic Species

Double-crested Cormorants on Middle Island (Negligible Impact; localized)

Extensive damage to vegetation on Middle Island (Point Pelee National Park), has been caused by high nesting densities of Double-crested Cormorants (*Phalacrocorax auritus*) (Kirk 2003; Hebert *et al.* 2005; Duffe 2006; Aquila Applied Ecologists 2007). Cormorants cause direct damage to trees by physically breaking branches and stripping foliage for nesting material, and by the combined weight of birds and nests (Korfanty *et al.* 1999). In addition, guano deposits on trees and leaves reduce photosynthetic efficiency and impact tree health by making trees more susceptible to insects or disease (Hebert *et al.* 2005). The presence of high numbers of birds can also alter microclimate (humidity) and wind velocity, which may make trees more susceptible to disease, insects or windthrow (Aquila Applied Ecologists 2007). Moreover, subcanopy vegetation may be damaged by: 1) direct deposits of guano which enhances potassium, nitrogen, ammonium levels and which at certain thresholds become toxic to some plant species and favour noxious weeds and exotic species (Britto and Kronzucker 2002); 2) increased litter fall from cormorant nesting activity (Hobara *et al.* 2001); and 3) increased light penetration from canopy opening thus changing the species composition of the shrub and herbaceous layer (Weseloh and Brown 1971). Some of these factors may interact; for example, reductions in canopy cover caused by nesting cormorants can reduce relative humidity and create higher wind velocities, which in turn can exacerbate ammonium toxicity to plants (Krastina and Loseva 1975, Haynes and Goh 1978).

Of the Blue Ash trees surveyed by Jalava in 2007 (Jalava *et al.* 2008), three were dead, one was dying and many other trees showed signs of severe stress as a result of cormorant nesting. However, this was only a partial survey. The most recent complete surveys of Blue Ash by Parks Canada in 2012 indicated that of the 240 living trees inventoried, 16.7% (40) were severely damaged (≤ 50% alive), 52.1% (125) were moderately damaged (51-89% living), and 31.3% (75) were healthy (90% living). Five trees were dead. There was minimal regeneration of Blue Ash, perhaps because of soil acidification from cormorant guano or ammonium toxicity (Dobbie, pers. comm. 2012). Interestingly, Boutin *et al.* (2011) found seeds of plant species at risk in the seedbank, indicating that Middle Island has potential for restoration following reduction in cormorant numbers through management.

It should also be mentioned in relation to Point Pelee National Park that large numbers of Wild Turkeys frequent the area. Because turkeys eat Blue Ash seeds, they have the potential to influence regeneration within the national park and also on Pelee Island (Otis, pers. comm. 2013).

Natural Systems Modification: Fire Suppression and Water Management (Impact negligible)

Blue Ash requires disturbance to create conditions suitable for regeneration. In the Carolinian life zone, gap-phase disturbance was the predominant natural disturbance and included events such as ice-storms, windfalls, drought, floods, insect attacks and fire to create conditions for regeneration (Cadman *et al.* 2007). The types of natural disturbance factors that occurred historically for the Blue Ash vary depending on site characteristics. For example, on dry limestone soils in alvar habitat or oak savannahs, disturbances were site-specific but included flooding, fire and drought, which all limited plant succession (Bond and Wilgren 1996; NCC 2008).

Following the storms of 1972/73, the shoreline of Pelee Island was fortified with armour stone and a series of dykes built inland for drainage. Thus natural flooding has been effectively prevented. Fire, both of natural and Aboriginal origin, also played an important role in natural disturbance but has been suppressed over the last 100-200 years (NCC 2008).

On floodplain sites in the Thames and Sydenham Rivers, there is little information on the periodicity of natural disturbance or the extent to which this has been influenced by human modification of landscapes.

Hydrological impacts are widespread in southern Ontario, resulting from extensive tiling of agricultural lands, irrigation, dams, channelization and re-routing of watercourses. These types of activities affect the quality of soil and other ecological functions in woodland and swamp communities. In some cases tile drains are extended into woodlots (Jalava *et al.* 2007) and this could potentially impact soil moisture regime and growing conditions for Blue Ash. General reductions in soil moisture have been considered a threat to other tree species at risk in Ontario (Jalava *et al.* 2007). These effects could be exacerbated by climate change, particularly current warming trends.

Livestock Farming and Ranching: Grazing and Trampling by Cattle, Horses and Sheep (Negligible Impact)

Livestock grazing may pose a threat to Blue Ash regeneration in riparian floodplain areas but the current scope of these activities is limited. From the late 19th century through to the 1970s, most woodlots in stream valley side slopes and adjacent high ground were pastured to cows, horses and sheep and were much more open in nature than at present. By 2013, few woodlots had grazing livestock.

Livestock can have two main effects on Blue Ash regeneration and recruitment. First, they trample riparian vegetation on river banks and adjacent areas, which inhibits seedling establishment. Second, livestock grazing creates open vegetation with extensive grass cover and abundant rodent populations. Blue Ash seedlings and saplings appear particularly susceptible to girdling by rodents (an indirect result of grazing; Mills and Craig 2008). Supporting this contention, Mills and Craig (2008) did not find Blue Ash in reforestation areas with sod, even though these areas were adjacent to woodlots with Blue Ash regeneration. However, they did find Blue Ash regenerating in areas reforested with hawthorn (*Cratageus* spp.) when the hawthorn was being shaded out in the stand and meadow plants and rodent populations were declining (Mills and Craig 2008). At the A.W. Campbell Conservation Area, it was also notable that in a grass sod area surrounding a 40 cm dbh Blue Ash tree growing along a lane, seedlings were found once the grass was shaded out.

The absence of livestock grazing in recent years could explain the large numbers of sapling and seedling Blue Ash found in recent surveys at some sites Mills and Craig (2008) as well as the skewed age distribution at some sites (Craig, pers. comm. 2013). At some of these sites (e.g., McAlpine Tract) there were very large numbers of seedlings and saplings but still strong evidence of deer browsing, suggesting that in some situations deer do not have a large impact on recruitment.

Additional possible threats are currently considered to have negligible impact on Blue Ash, in part because the riparian habitats in which most trees occur can be expected to have minimal impacts from development, recreational activities, agriculture and forestry, and because Blue Ash occurs in many subpopulations that are typically at low density, with trees scattered over a broad area. However, it should be noted that while the habitat of Blue Ash is considered marginal for traditional crops, it may be suitable for biofuel crops (Smith *et al.* 2013). Similarly, while the cattle industry has declined in southern Ontario, small scale livestock grazing by horses and goats has the potential to impact some sites. Additional activities such as corridor maintenance for power lines, quarrying and other resource extraction activities may have local impacts at individual sites.

Number of Locations

Uncertainly about the severity and scope of threats to Blue Ash complicate the assessment of the number of locations. The two most significant current threats, impact of browsing by White-tailed Deer and impacts of EAB, are known or suspected to vary among sites. Key to estimating the number of locations is the need to determine the most important threat and the scope over which it can act quickly.

For deer, many different management units exist, potentially resulting in independent impact of deer browsing at different sites. However, a tentative classification of levels of impact of White-tailed deer can be based on land ownership. Lands under the management of conservation authorities are potentially under a single broad authority, in which deer numbers are proposed to be managed primarily by hunting. Private land represents a second type of regime, on which deer management is not expected. At Point Pelee, active deer management in the form of culling represents a third management scheme. Each of these (with broad caveats) is likely to result in differing levels of impact on Blue Ash regeneration. This approach yields 3 locations (Pelee Island and Middle Island, which lack deer, would not be part of this designation).

Considering the information on Wildlife Management areas suggests that recruitment may be lower in areas where White-tailed deer are inferred to be increasing (based on kill numbers), moderate in areas where deer are fluctuating, and high in areas where deer numbers are declining. This suggests that 3 locations may also be appropriate with this approach (again, excluding Pelee Island and Middle Island).

For EAB, there is minimally one location (if EAB acts and is managed the same way everywhere) up to the number of sites where EAB is present. Given the limited impact of management on the progression of invasion of EAB to date, it seems reasonable to assess the threat of EAB as a single location.

On Middle Island, impacts of Double-crested Cormorants are thought to be the most significant threat (1 location added to the total from other subpopulations).

Thus, considering deer as the greatest threat in most areas leads to 5 locations: 3 based on deer, one for Pelee Island (based on EAB), and one for Middle Island (based on Double-crested Cormorants). If EAB is considered the greatest threat, the number of locations could be 2: one for EAB and one for Middle Island (based on Double-crested Cormorants).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

COSEWIC first assessed Blue Ash as Special Concern in April 1983, confirmed same status in November 2000, and the wildlife species was last assessed as Threatened in November 2014. Listed as a species of Special Concern (Schedule 1) under the Canadian federal *Species at Risk Act* (SARA 2003), Blue Ash also comes under Schedule 5 in the Ontario *Endangered Species Act*, 2007. Schedule 5 species are in transition and to be listed as Special Concern. Development or site alteration in the habitat of threatened or endangered species is prohibited by the *Provincial Policy Statement* (PPS) in Ontario but there is no mention of species of Special Concern (Ministry of Municipal Affairs and Housing 2012). Environmental assessment acts (e.g., the provincial *Ontario Environmental Assessment Act* and the federal environmental assessment legislation under the *Canadian*

Environmental Assessment Act) provide some protection from development activities that could have detrimental impacts on the Blue Ash. Plant life is also protected under the *Plant Protection Act* by the Canadian Food Inspection Agency (CFIA) by preventing the importation, exportation and spread of pests and by controlling or eradicating pests in Canada.

Non-Legal Status and Ranks

Although it is considered globally secure (G5), the Blue Ash is vulnerable nationally in Canada (N3) and unranked (not yet assessed) in Ontario (S3?). It is nationally secure in the United States (N5), but secure (S5) in only one state (Kentucky). Blue Ash is considered critically imperiled (S1) in Pennsylvania, West Virginia, Wisconsin and Iowa, imperiled (S2) in Kansas, and Mississippi, and vulnerable (S3) in Virginia. It is S1S2 in Georgia and S2S3 in Oklahoma. Blue Ash is unranked (not yet assessed) in Michigan, Alabama, Missouri, Ohio, Minnesota, Texas, Arkansas, Illinois, Tennessee, and Indiana. It was falsely reported (SNA) in New York state (NatureServe 2013). In the General Status of species at risk in Canada the Blue Ash is listed as 'Sensitive' (Wild Species 2010).

Habitat Protection and Ownership

The protection status of Blue Ash sites surveyed in 2012/2013 is shown in Table 2. Populations of Blue Ash located on provincially owned land and conservation areas are potentially protected. Subpopulations at Point Pelee National Park (including the population on Middle Island) are protected under the Federal Parks Acts (*Canada National Parks Act*).

In Ontario, the protection status of sites containing Blue Ash was summarized by Henson and Brodribb (2005). In Ecodistrict 7E1 (Chatham), 42% of sites with Blue Ash are in provincially significant Areas of Natural and Scientific Interest (ANSIs), with 8% each in federally protected lands, and provincially protected lands; 50% of sites were in all conservation lands (8 sites with Blue Ash in portfolio, 67% of sites in portfolio). In Ecodistrict 7E2 (St. Thomas), 11% of sites with Blue Ash occurred in ANSIs, 8% in Conservation Areas (CAs); 22% of the sites were in all conservation lands (8 sites with Blue Ash in portfolio, 22% of all sites in portfolio). In Ecodistrict 7E6 (Stratford), there was only one site.

On Pelee Island, Blue Ash occurs on sites owned by the Nature Conservancy of Canada including Brown's Road Alvar and Red Cedar Savanna (B. Ivey E-W/ road - NCC and Pelee Island Winery). Other sites on Pelee Island include Verbeek Savanna (Lighthouse Point Provincial Nature Reserve) and Fish Point, both owned by Ontario Parks. Stone Road Alvar is owned jointly by Ontario Nature and the Township of Pelee.

St. Clair Region Conservation Authority lands include A. W. Campbell CA, McKeough Dam, McAlpine Tract, Property 82, Property 83, Property 91, Property 92, Reid CA, and Shetland Conservation Area. Newport Forest (Thames River, 3.5 km sw of Wardsville) and Wardsville Woods are owned by the Thames Talbot Land Trust.

Provincial Parks include Komoka Provincial Park (Province of Ontario). Most other sites are on private land.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

The author extends special thanks to the landowners who gave permission to survey Blue Ash on their properties. John Ambrose, Donald Craig, Paul O'Hara and Gerry Waldron provided wonderful help with field surveys during the summer and fall of 2012. In addition, Cathy Quinlan, Brandon Williamson, and Brenda Gallagher of the Upper Thames Region Conservation Authority visited the Kains Woods and Fanshawe Forest sites for which the author is most grateful. Tim Payne of the St. Clair Region Conservation Authority helped Donald Craig with surveys of the McAlpine Tract and A. W. Campbell Conservation Area.

Bill Roesel and Paul Pratt provided the latest information on Blue Ash trees in the City of Windsor. Special thanks are also due to Parks Canada staff who surveyed Middle Island in 2012: Heidi Brown, Tammy Dobbie, Josh Keitel, Kevin LeClair, Steve McCanny, Valerie Minelga, Kelly Scott, and Rachel Windsor (Thorndyke), as well as Gard Otis and students who conducted the inventory of Blue Ash trees on the mainland of Point Pelee National Park in 2005 and 2006: these included Barbara Bleko, Holly Dodds, Sally-Jo Gallant, Victoria Moran, and Laura Robson. Jarmo Jalava conducted the 2007 survey on Middle Island.

John Ambrose and especially Donald Craig also helped tirelessly with numerous questions about Blue Ash.

The following provided comments on earlier drafts of this report: Michael J. Oldham (Natural Heritage Information Centre, Ontario Ministry of Natural Resources), Vivian R. Brownell, Eric Snyder (Species at Risk Branch, OMNR), Bill Parker (Ontario Forest Research Institute, OMNR); Ruben Boles, Joanna James, Julie Nadeau (Canadian Wildlife Service Headquarters); Bruce Bennett (SSC co-chair), Marilyn Anions, Sean Blaney, and the late Jane Bowles (SSC members); and Tammy Dobbie (Point Pelee National Park, Parks Canada Agency). Extensive editorial comments were provided by Jeannette Whitton for which the author is most grateful.

The following also provided help or advice on people to contact:

Alison Barr, Canadian Food Inspection Agency, St. Catherine's, Ontario, Emerald Ash Borer Specialist.

Dawn R. Bazely, Biology Department, York University, Professor.

Ann Bonner, Division of Forestry, Ohio Department of Natural Resources.

Lisa Bowers, Ohio Division of Forestry, ODNR Urban Forester.

Graham Buck, Ontario Ministry of Natural Resources, Guelph District, Species at Risk Biologist.

Vivian Brownell, Ontario Ministry of Natural Resources, Peterborough, Species at Risk Biologist.

Julian J. N. Campbell, Consultant, Bluegrass Woodland Restoration Center, 3525 Willowood Road, Lexington, Kentucky.

Shelley Carson (Stewart), University of Guelph, Guelph, Ontario, Ph D candidate.

Robert Davies, Essex Region Conservation Authority, Forest Operations Technician.

Sandy Dobbyn, Ontario Parks, Ontario Ministry of Natural Resources, Southwest Zone, Ecologist.

Jennifer Doubt, Canadian Museum of Nature, Ottawa, Ontario.

Ken A. Elliot, Ministry of Natural Resources, Southern Science and Information, London, Ontario, R. P. F.

Dave Fraser, Scientific Authority Assessment A/Manager BC CDC, Ecosystem Branch Conservation Planning Section, Ministry of Environment, Government of British Columbia

Martina Furrer, Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Biodiversity Information Specialist.

Andy J. Green, Wetland Ecology Department, Doñana Biological Station-CSIC, Spain, Waterfowl Biologist.

Daniel A. Herms, Department of Entomology, College of Food, Agricultural and Environmental Sciences, Ohio Agricultural Research and Development Center, Wooster Ohio, Professor and Chair.

Jarmo Jalava, Carolinian Canada Coalition, Director, Ecosystem Recovery.

Neil Jones, ATK Scientific Project Officer & ATK Coordinator, COSEWIC Secretariat.

Dan Kraus, Nature Conservancy of Canada, Ontario Region, Manager of Conservation Science and Planning.

Barry Lyons, Research Scientist, Natural Resources Canada, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

Patrick Nantel, Parks Canada Agency, Headquarters, Gatineau, Quebec.

Michael J. Oldham, Natural Heritage Information Centre, Ontario Ministry of Natural Resources, biologist.

Sara Tanis, Department of Entomology, Michigan State University, Post-doctoral Research Associate.

Christopher J. Whelan, Illinois Natural History Society, University of Illinois, Grassland Ecologist

Rachel Windsor, Point Pelee National Park, Parks Canada Agency, Leamington, Ontario, Resource Conservation Technician.

Mark Wilthew, Ohio Division of Forestry, Middlefield, Ohio, Service Forestry Coordinator, OFTL Coordinator.

INFORMATION SOURCES

Ambrose, J. D., and S. W. Aboud. 1983. COSEWIC status report on the Blue Ash *Fraxinus quadrangulata* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. 27 pp.

Ambrose, J. 2012 and 2013. *Email correspondence and phone conversations to D. A. Kirk.* Swallow Haven Farm, Pelee Island. June 2012-September 2013.

Aquila Applied Ecologists 2003. Impacts of Double-crested Cormorant (*Phalacrocorax auritus*) populations on the biodiversity of islands in western Lake Erie: Management recommendations. Report to Point Pelee National Park of Canada, Parks Canada Agency, Leamington, Ontario.

Bacles, C. F. E., J. Burczyk, A. J. Lowe, and R. A. Ennos, 2005. Historical and contemporary mating patterns in remnant populations of the forest tree *Fraxinus excelsior* L. Evolution 59**:** 979–990.

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

Bendix, J., and C. R. Hupp. 2000. Hydrological and geomorphological impacts on riparian plant communities. Hydrological Processes 14: 2977-2990.

Bond, W.J., and B.W. van Wilgen. 1996. Fire and Plants (Population and Community Biology Series 14). Chapman & Hall, New York.

Boutin, C., and B. Jobin. 1998. Intensity of agricultural practices and effects on adjacent habitats. Ecological Applications 8: 544-557.

Boutin, C., T. Dobbie, D. Carpenter, and C. E. Hebert. 2011. Effects of Double-crested Cormorants (*Phalacrocorax auritus* Less.) on island vegetation, seedbank and soil chemistry: Evaluating island restoration potential. Restoration Ecology 19: 720-727.

Britto, D.T., and H. J. Kronzucker. 2002. NH_4^+ toxicity in higher plants: a critical review. Journal of Plant Physiology 159:567-584.

Burke, D.M., and E. Nol. 1998. Edge and fragment size effects on the vegetation of deciduous forests in Ontario, Canada. Natural Areas Journal 18: 45–53.

Burns, R.M., and B. H. Honkala. 1990. Silvics of North America. USDA Forest Service, Timber Management Research Agriculture Handbook 654, Washington, DC.

Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier (eds). 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Birds Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, xxii + 706 pp.

Campbell, Julian. *Phone conversation with D. A. Kirk.* April 2014. Consultant, Bluegrass Woodland Restoration Center, Lexington, Kentucky.

Campbell, J. in preparation. The relationship of herbivory to patterns of vegetation within an abandoned hay-field adjacent to old-growth at Griffith Woods, Harrison County, Kentucky. Bluegrass Woodland Restoration Center, 3525 Willowood Road, Lexington,Kentucky 40517.

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.

CFIA (Canadian Food Inspection Agency). 2013. New CFIA measures protect uninfested areas of Canada from the Emerald Ash Borer. News release June 2013. URL: http://www.inspection.gc.ca/about-the-cfia/newsroom/news-releases/2013-06-13/eng/1371136996878/1371137004305 [accessed October 2013].

City of Windsor. 2004. City of Windsor Parks History. Department of Parks and Recreation. http://www.citywindsor.ca/residents/parksandforestry/City-Parks/Pages/City-Parks.aspx [accessed September 2014].

Côté, S.D., Rooney, T.P., Tremblay, J., Dussault, C., Waller, D.M. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution, and Systematics. 35, 113, 113

Craig, Donald. 2012 and 2013. *Email correspondence and phone and field conversations with D. A. Kirk.* Retired Forester, St. Clair Region Conservation Authority. May 2012 to September 2013.

Crins, W.J., Gray, P.A., Uhlig, P.W.C., Wester, M.C. 2009. The Ecosystems of Ontario, Part I: Ecozones and Ecoregions. Ontario Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR- 01, 71pp.

Davies, Robert. 2013. *Email correspondence with D. A. Kirk*. Forestry, Operations Technician, Essex Region Conservation Authority, Essex, Ontario.

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. Oikos 67 (2): 93-103.

De Groot, P., W. D. Biggs, D. B. Lyons, T. Scarr, E. Czerwinski, H. J. Evans, W. Ingram and K. Marchant. 2006. A visual guide to detecting emerald ash borer damage. Canadian Forest Service and Ontario Ministry of Natural Resources.

Dobbie, Tammy. 2012 and 2013. *Email correspondence with D. A. Kirk.* December 2012, September 2013. Ecologist, Point Pelee National Park of Canada, Leamington, Ontario.

Duan, J.J., L. S. Bauer, K. J. Abell, J. P. Lelito, and R. V. 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). Journal of Economic Entomology 106: 1145-1154.

Duffe, J. 2006. Impacts of Double-crested Cormorants nesting on western Lake Erie islands. M.S. Thesis, Carleton University. Ottawa, Ontario.

Eastern Native Tree Society 2013. Bigtree maxlist. URL www.nativetreesociety.org/bigtree/maxlist/Max%20list%202.1.xls*. Accessed August 2013.*

Enright, John. 2013. *Email correspondence to D. A. Kirk via Cathy Quinlan.* October 2013. Upper Thames River Conservation Authority.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics. 34: 487-515.

Farrar, J. L. 1995. Trees in Canada. Fitzhenry & Whiteside, Markham, Ontario.

Fraser, Dave. 2013. *Email correspondence to D. A. Kirk*. Unit head, Ecosystem Branch Conservation Planning Section, Ministry of Environment, Government of British Columbia.

Gallagher, B. 2012 and 2013. *Email correspondence to D. A. Kirk*. Forester, Thames River Conservation Authority.

Gandhi, K. J. K, 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: 1839-1846.

Google Earth 2013. Google Earth. Available at: http://www.google.com/earth/ [accessed October 2013].

Green, Andy, J. 2013. *Email correspondence with D. A. Kirk*. October 2013. Professor, Wetland Ecology Department, Doñana Biological Station_CSIC, c/o Américo Vespucio s/n 41902, Sevilla, Spain.

Griffith, D.M., D. M. DiGiovanni, T. L. Witzel, and E. H. Wharton. 1993. Forest statistics for Ohio, 1991. USDA Forest Service, Northeastern Forest Experiment Station, Resource Bulletin NE-128.

Harper, K.A., S. E. Macdonald, P. J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Euskirchen, D. Roberts, M. S. Jaiteh, and P.-A. Esseen. 2005. Edge influence on forest structure and composition in fragmented landscapes. *Conservation Biology*, 19: 768–782.

Haynes, R.J., and K.M. Goh. 1978. Ammonium and nitrate nutrition of plants. Biological Reviews 53:465-510.

Hebert, C.E., D.V. Weseloh, E.M. Senese and G.D. Haffner. 2005. Unique island habitats may be threatened by Double-crested Cormorants. Journal of Wildlife Management 69(1):68-76.

Henson, B. L., and K. E. Brodribb. 2005. Great Lakes Conservation Blueprint for Terrestrial Biodiversity, Volume 2: Ecodistrict Summaries. Nature Conservancy of Canada and Ontario Ministry of Natural Resources.

Herms, Daniel. 2013. *Email correspondence with D. A. Kirk*. October 2013. Professor and Chair, Department of Entomology, College of Food, Agricultural and Environmental Sciences, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster, Ohio, USA.

Hewitt, N., and M. Kellman. 2002. Tree seed dispersal among forest fragments: II. Dispersal abilities and biogeographical controls. Journal of Biogeography 29: 35-363.

Hewitt, N., and M. Kellman. 2004. Factors influencing tree colonization in fragmented forests: an experimental study of introduced seeds and seedlings. Forest Ecology and Management 191: 39-59.

Hobara, S., T. Osono, K. Koba, N. Tokuchi, S. Fujiwara, and K. Kameda. 2001. Forest floor quality and N transformations in a temperate forest affected by avian-derived N deposition. Water, Air, and Soil Pollution 130:679-684.

Horsely, S. B., S. L. Stout and D. S. DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwoods forest. Ecological Applications 13: 98-118.

Hulme, P. E. 1998. Post-dispersal seed predation: Consequences for plant demography and evolution. Perspectives in Plant Ecology. Evolution and Systematics 1: 32-46.

Hynes, K.E. 2002. The role of light in Carolinian forests of southwestern Ontario, Canada: An indicator of disturbance and predictor of ecosystem recovery. M.S. Thesis, York University, Toronto.

Hynes, K., Koh, S., Mclachlan, S., Timciska, M., Bazely, D.R., 2002. Shedding light on the problem of deer overgrazing in Carolinian forests. In: Bondrup, S., Munro, N., Nelson, G., Martin-Willison, J.H., Herman, T.B., Eagles, P. (Eds.), Proceedings of the 4th International Conference on the Science and Management of Protected Areas Conference. Science and Management of Protected Areas Association, Wolfville, pp. 285–291.

Jalava, Jarmo. 2013. *Email correspondence with D. A. Kirk*. October 2013. Director, Ecosystem Recovery, Carolinian Canada Coalition, London, Ontario.

Jalava, J.V., J.D. Ambrose and N. S. May. 2007. Draft National Recovery Strategy for Carolinian Woodlands and Associated Species at Risk: Phase I. Carolinian Canada Coalition and Ontario Ministry of Natural Resources, London, Ontario. viii + 68 pp.

Jalava, J.V., P.L. Wilson and R.A. Jones. 2008. COSEWIC-designated Plant Species at Risk Inventory, Point Pelee National Park, including Sturgeon Creek Administrative Centre and Middle Island, 2007, Volume 1: Summary Report & Volume 2: Managed Area Element Status Assessments. Prepared for Parks Canada Agency, Point Pelee National Park Park, Leamington, Ontario. Vol. 1 vii + 126 pp., Vol. 2 ii + 103 pp.

Kamstra, J.M., M.J. Oldham, and P.A. Woodliffe. 1995. A life science inventory and evaluation of six natural areas in the Erie islands, Essex County, Ontario: Fish Point Provincial Nature Reserve, Lighthouse Point Provincial Nature Reserve, Stone Road Complex, Middle Point, East Sister Island Provincial Nature Reserve and Middle Island. Aylmer District, Ontario Ministry of Natural Resources, Aylmer, Ontario, Canada.

Kerr, J.T., and J. Cihlar. 2004. Patterns and causes of species endangerment in Canada. Ecological Applications 14:743–753.

Kirk, David A. 2013. Blue Ash *Fraxinus quadrangulata* inventory for COSEWIC update 2012. Draft Report to COSEWIC Secretariat, December 2012.

Kirk, David A. 2003. Impacts of Double-crested Cormorant (*Phalacrocorax auritus*) populations on the biodiversity of islands in western Lake Erie: Management recommendations. Report to Point Pelee National Park of Canada, Leamington, Ontario and Parks Canada Headquarters, Gatineau, Québec.

Kirk, Donald A. 1994. Stone Road Alvar, Pelee Island: Management of an unusual oak savannah community type in the western Lake Erie archipelago. Wickett, Robert G., *et al.*, Editor *Proceedings of the Thirteenth North American Prairie Conference : spirit of the land, our prairie legacy : held 6-9 August 1992, Windsor, Ontario, Canada* Dept. of Parks and Recreation, 1994.

Knight, Kathleen. 2012. *Email correspondence to D. A. Kirk.* 16 December, Research Ecologist, USDA Forest Service, Northern Research station, Delaware, Ohio, USA.

Koh, S., *et al.* 1996. Impact of herbivory of white-tailed deer (*Odocoileus virginianus*) on plant community composition. Aspects of Applied Biology 44:445-450.

Koh, S., D. R. Bazely and M. Timciska. 1999. Grazing impacts of White-tailed Deer or “Culling Bambi to save the forest”. Parks and Protected Areas Research in Ontario. Pp. 187-196.

Koh, S., D. R. Bazely, A. J. Tanentzap, D. R. Voight, and E. Da Silva. 2010. *Trillium grandiflorum* height is an indicator of white-tailed deer density at local and regional scales. Forest Ecology and Management 259: 1472-1479.

Korfanty, C., W. Miyasaki, and J. L. Harcus. 1999. Review of the population status and management of Double-crested Cormorants in Ontario. Pages 131-146 in M. E. Tobin, editor. Symposium on Double-crested Cormorants: Population status and management issues in the Midwest, USDA Technical Bulletin No. 1879.

Kramer, A. T., J. L. Ison, M. V. Ashley, and H. F. Howe. 2008. The paradox of forest fragmentation genetics. Conservation Biology 22 (4): 878-885.

Krastina, E.E., and A.S. Loseva. 1975. The effect of the type of nitrogen nutrition on water uptake by plants and the concentration and ratio of cations in various organs. Isvestiva Timiryazevskoi Sel skokhozyaistvennoi Akademii 5:13-21.

Larson, B. M. H., and G. Waldron. 2000. Catastrophic windthrow in Rondeau Provincial Park, Ontario. *Canadian Field-Naturalist* 114: 78–82.

Larson, B.M., J.L. Riley, E.A. Snell and H.G. Godschalk. 1999. The Woodland Heritage of Southern Ontario: A Study of Ecological Change, Distribution and Significance. Federation of Ontario Naturalists, Don Mills, ON. 262 pp.

Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig and S. McMurray. 1998. Ecological Land Classification for Southern Ontario: First Approximation and its Application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02.

Logue, J. B., N. Mouquet, H. Peter, H. Hillebrand and The Metacommunity Working Group. 2011. Empirical approaches to metacommunities– a review and comparison to theory. Trends in Ecology and Evolution 26: 482–491.

Lowe, A. J., D. Boshier, M. Ward, C. F. E. Bacles, and C. Navarro. 2005. Genetic resource impacts of habitat loss and degradation: reconciling empirical evidence and predicted theory for Neotropical trees. Heredity 95 (4): 255-273.

MacGowan, B. J. 2003. Designing hardwood tree plantings for wildlife. Department of Forestry and Natural Resources, Purdue University. Accessed December 2012. Available at http://www.ces.purdue.edu/extmedia/FNR/FNR-213.pdf

Managhan, S., D. A. Kirk, and J. Kamstra. 1992. Stone Road Alvar management plan. Federation of Ontario Naturalists, Essex Region Conservation Authority, Ontario Ministry of Natural Resources. Pp 1-78.

Martin, A. C., H. S. Zim, and A. L. Nelson. 2011. American Wildlife and Plants: A Guide to Wildlife Food Habits: The Use of Trees, Shrubs, Weeds, and Herbs by Birds and Mammals of the United States. Dover publications, New York, USA.

McCauley, Cam. 2014. *Email correspondence to D. A. Kirk.* A/Management Biologist, Ministry of Natural Resources, Alymer Office, Alymer, Ontario.

McCullough, D.G., T. M. Poland, and D. Cappaert. 2009a. Attraction of the emerald ash borer to ash trees stressed by girdling, herbicide treatment, or wounding. Canadian Journal of Forest Research 39(7): 1331–1345.

McCullough, D.G., T. M. Poland, A. C. Anulewicz, and D. Cappaert. 2009b. Emerald ash borer (Coleoptera: Buprestidae) attraction to stressed or baited ash trees. Environmental Entomology 38(6): 1668–1679.

Miller, Stephanie. 2012 and 2013. *Email correspondence with D. A. Kirk.* December 2012, September 2013. Regional Urban Forester, Ohio DNR Division of Forestry, Findlay, Ohio.

Mills, C., and D. Craig. 2008. Woodland species at risk inventory. March 2008, St. Clair Region Conservation Authority.

Minelga, V. 2012. *Email correspondence with D. A. Kirk.* June-August 2012. Acting Park Ecologist, Point Pelee National Park of Canada, Leamington, Ontario.

Missouri Department of Conservation. 2013. How old is that tree? URL: http://mdc.mo.gov/your-property/your-trees-and-woods/backyard-tree-care/how-old-tree [accessed September 2013].

Moritz, C., C. N. Meynard, V. Devictor, K. Guizien, C. Labrune, J.-M. Guarini and N. Mouquet. 2013. Disentangling the role of connectivity, environmental filtering, and spatial structure on metacommunity dynamics. Oikos 122: 1401–1410.

Muirhead, J. R., B. Leung, C. van 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: 71-79.

Myers, J. A., M. Velland, and S. Gardescu. 2004. Seed dispersal by white-tailed deer: implications for long-distance dispersal, invasion, and migration of plants in eastern North America. Oecologia 139:35-44.

Nature Conservancy of Canada (NCC). 2008. Management Guidelines: Pelee Island Alvars. NCC-Southwestern Ontario Region, London, Ontario. 43 pp.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer [accessed October, 2013].

North-South Environmental Inc. 2004. Point Pelee National Park of Canada Analysis & Summary Report of 1990 Vegetation Management Objectives. 105 pp + 2 maps.

Ohio Department of Natural Resources (ODNR) 2013. Blue Ash *Fraxinus quadrangulata*. Available at: http://www2.ohiodnr.com/forestry/blueash [accessed October 2013].

Oldham, M.J., and S.R. Brinker. 2009. Rare Vascular Plants of Ontario, Fourth Edition. Natural Heritage Information Centre, Ontario Ministry of Natural Resources. Peterborough, Ontario. 188 pp.

Oldham, M. 2012. *Email correspondence with D. A. Kirk.* 18 June, and 17 December 2012. Biologist, Ontario Natural Heritage Information Centre, Peterborough, Ontario.

OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs). 2014. Historical provincial estimates by crop (1981-2013). Available at: http://www.omafra.gov.on.ca/english/stats/crops/estimate_hist_metric.htm#Grain Corn [accessed April 2014].

OMNR (Ontario Ministry of Natural Resources). 2013. Emerald Ash Borer (*Agrilus planipennis*). Available at http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STEL02_166994.html [accessed September, 2013].

OMNR (Ontario Ministry of Natural Resources). 2014. White-tailed Deer Management in Ontario. Available at: http://www.mnr.gov.on.ca/en/Business/FW/2ColumnSubPage/STDPROD_097134.html [accessed April 2014].

Ontario Nature. 2007. Forest fragmention. Available at: www.ontarionature.org/discover/resources/PDFs/.../fragmentation.pdf [accessed October 2014].

Ontario Parks. 2010. Komoka Park Management Plan. Queen's Printer for Ontario, Ontario Parks, Province of Ontario.Ostfeld, R. S., R. H. Manson, and C. D. Canham. 1997. Effects of rodents on survival of tree seeds and seedlings invading old fields. Ecology 78: 1531-1542.

Otis, G. and S. Stewart. 2011. Supplementary EAB Report for Point Pelee National Park 2010: Emerald Ash Borer at Point Pelee National Park: Current and future distribution and impact at Point Pelee. Department of Environmental Biology, University of Guelph, Guelph, Ontario. Report to Parks Canada Agency.

Otis, Gard. 2012 and 2013. *Email correspondence to D. A. Kirk.* July-December 2012, September 2013. Professor, University of Guelph, Guelph, Ontario.

Palmini, Roger. 2013. *Email correspondence with D. A. Kirk*. GIS Database Technician, Essex Region Conservation Authority, Essex, Ontario.

Parks Canada Agency. 2011. Detailed Assessment for the Blue Ash (*Fraxinus quadrangulata*) in Point Pelee National Park of Canada. Species at Risk Detailed Assessments. Parks Canada Agency, Ottawa. 8 pp.

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

Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. Web site: http://www.nrs.fs.fed.us/atlas/tree, Northern Research Station, USDA Forest Service, Delaware, Ohio. (accessed August 2013).

Pratt, Paul. 2013. *Email correspondence with D. A. Kirk.* September 2013. Ojibway Nature Centre, City of Windsor, Ontario.Quinlan, Cathy. 2012 and 2013. *Email correspondence to D. A. Kirk.* July 2012 – September 2013. Terrestrial Biologist, Upper Thames River Conservation Authority.

Quinlan, Cathy. 2012 and 2013. *Email correspondence to D. A. Kirk.* July 2012 – September 2013. Forester, Upper Thames River Conservation Authority.

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.

Rieske-Kinney, Lynne. 2014. *Email correspondence to D. A. Kirk.* May 2014. Professor, Forest Entomology, University of Kentucky, Lexington, Kentucky, USA.

Roesel, Bill. 2012 and 2013. *Email correspondence to D. A. Kirk.* September 2012 and September 2013. Forester, City of Windsor, Windsor, Ontario.

Rooney, T. P., and D. M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management 181: 165-176.

Russell, F. L., D. P. Zippin, and N. L. Fowler. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations and communities: a review. American Midland Naturalist 146: 1-26.

Salafsky, N., D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H. M. Butchart, B. Collen, N. Cox, L. L. Master, S. O'Connor and D. Wilkie. 2008. A standard lexion for biodiversity conservation: Unified classifications of threats and actions. Conservation Biology 22: 897-911.

Smith, A. L., N. Klenk, S. Wood, N. Hewitt, I. Henriques, N. Yan and D. R. Bazely. 2013. Second generation biofuels and bioinvasions: An evaluation of invasive risks and policy responses in the United States and Canada. Renewable and Sustainable Energy Reviews 27: 30-42.

Strobl, S., and D. Bland. 2013. A silvicultural guide to managing southern Ontario forests. Web site: http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@forests/documents/document/stdprod_100100.pdf [accessed August 2013].

Tanis, S. R. 2013. Host plant interactions between Emerald Ash Borer and five *Fraxinus* species. PhD dissertation, Michigan State University.

Tanis, S. R., and D. G. McCullough. 2012. Differential persistence of Blue Ash and White Ash following Emerald Ash Borer invasion. Canadian Journal of Forest Research 42: 1542-1550.

Tanentzap, A. J., D. R. Bazely, S. Koh, M. Timciska, E. G. Haggith, T. J. Carleton, and D. A. Coomes. 2011. Seeing the forest for the deer: Do reductions in deer disturbance lead to forest recovery? Biological Conservation 144: 376-382.

Tanentzap, A. J., Kirby, K. J., and E. Goldberg. 2012. Slow responses of ecosystems to reductions in deer (Cervidae) populations and strategies for achieving recovery. Forest Ecology and Management 264: 159-166.

Thompson, W. L. (Editor). 2004. Sampling rare or elusive species. Concepts, designs and techniques for estimating population parameters. Island Press, Washington, USA.

Venter, O., N. N. Brodeur, L. Nemiroff, B. Belland, I. J. Dolinsek, and J. W. A. Grant. 2006. Threats to endangered species in Canada. *Bioscience* 56:903-910.

Waldron, G. 2003. Trees of the Carolinian Forest: A guide to species, their ecology and uses. Boston Mills Press, Erin, Ontario, Canada. 275 pp.

Waldron, G. 2012. Amherstburg, Ontario. *Email correspondence and phone conversations with D. A. Kirk*. July-December 2012.

Weseloh, D. V., and R. T. Brown. 1971. Plant distribution within a heron rookery. American Midland Naturalist 86: 57-64.

Whelan, Christopher. 2013. *Email correspondence with D. A. Kirk*. October 2013. Grassland Avian Ecologist, c/o Department of Biological Sciences M/C 066 University of Illinois at Chicago Chicago, IL 60607.

White, D. and M. Oldham 2000. COSEWIC Assessment and update for the Blue Ash *Fraxinus quadrangulata*. Committee on the Status of Endangered Wildlife in Canada. Ottawa, Ontario.

Wild Species 2010. Wild Species: The General Status of Wild Species in Canada. Website: http://www.wildspecies.ca/results.cfm?lang=e [accessed October 2013].

Williamson, Brandon. 2012 and 2013. *Email correspondence to D. A. Kirk.* July 2012 – September 2013. Forester, Upper Thames River Conservation Authority.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Dr. David Anthony Kirk is a consulting research ecologist and has worked for 25 years with the federal and provincial governments of Canada as well as non-government conservation organizations. He has a wide range of ecological and land use experience in different ecosystems ranging from tropical to arctic. His company (Aquila Conservation & Environment Consulting) specializes in science-based projects to inform the challenges of integrating human resource use with the conservation of biodiversity. This includes investigating the impact of human disturbance influences (especially agriculture and forestry) on biodiversity in anthropogenic landscapes, the application of species distribution models for use in spatial conservation planning, as well as state of the art literature reviews on current biodiversity challenges. He focuses on publication of peer-reviewed scientific articles in ecological and conservation journals as a forum for informing policy and management practice; reflecting this, David has written and/or co-authored more than 35 scientific papers and book chapters in the last 20 years. David also works extensively on the status, recovery and management of species at risk. He has written and/or co-authored 26 COSEWIC status reports and updates, as well as 9 draft recovery plans, 6 action plans and 9 management plans for species at risk, and a draft multispecies action plan for grasslands in south eastern Saskatchewan

COLLECTIONS EXAMINED

No collections were examined in preparation of this report.

Appendix 1. Threats Calculator for Blue Ash

Species or Ecosystem Scientific Name	Blue Ash		
Element ID		**Elcode**	
Date (Ctrl + ";" for today's date):	16/10/2013		
Assessor(s):	David Kirk, David Fraser, Jeannette Whitton, Vivian Brownell, Cathy Quinlan, Jill Crosthwaite, Mhairi McFarlane, Mike Oldham, Donald Craig, John Ambrose, Gard Otis, Dawn Bazely, Tammy Dobbie		
References:			

Overall Threat Impact Calculation Help:

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

Assigned Overall Threat Impact:	**B = High**
Impact Adjustment Reasons:	
Overall Threat Comments	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Likely limited in scope because many of the trees are in protected areas, pace of development is moderate, and choice of sites for housing tends to avoid these habitats.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Likely limited in scope because many of the trees are in protected areas, pace of development is moderate, and choice of sites for commercial areas tends to avoid these habitats.
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
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)	The habitat of Blue Ash is marginal for traditional crops, but may be suitable for non-traditional, including biofuels. Nonetheless, there is not expected to be much development in this area, based on current activities.
2.2	Wood & pulp plantations		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Fast growing *Salix* biofuel cultivars are among the possible crops.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Although cattle and dairy farms have declined, small scale farming activities, including grazing by sheep, goats and horses may impact recruitment.
2.4	Marine & freshwater aquaculture						
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Fracking could have an impact at some sites outside protected areas. Impacts are unknown, but likely to depend on whether ground water alteration occur, which would impact habitat of Blue Ash.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs)	A small number of sites have the potential to be impacted by aggregate extraction. Pelee Island has BA on the edges of an old limestone quarry, and other quarrying activities are possible.
3.3	Renewable energy						
4	Transportation & service corridors		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	
4.1	Roads & railroads						
4.2	Utility & service lines		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	Ongoing hydro corridor maintenance
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Intentional and unintentional removal of Blue Ash, in some cases associated with attempts to control the spread of Emerald Ash Borer, may impact trees both on private and public land.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	ATV and other trail use could impact recruitment at some sites.
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7	Natural system modifications						
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	
8.1	Invasive non-native/alien species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Concern is Emerald Ash Borer (EAB), which is expected to spread over the Ontario distribution of Blue Ash. However, there is evidence of resistance or tolerance to attack, with Blue Ash trees surviving EAB. Estimates of severity are based on current mortality, which could potentially change.
8.2	Problematic native species	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	White-tailed deer browsing poses the most widespread threat to Blue Ash. Based on general knowledge of impact of deer, it is expected that Blue Ash recruitment and sapling survival will be impacted whenever deer are abundant. Double-crested Cormorants, also impact Blue Ash at Middle Island.
8.3	Introduced genetic material						
9	Pollution		Unknown	Unknown	Unknown	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents		Unknown	Unknown	Unknown	High (Continuing)	
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						
11.2	Droughts						
11.3	Temperature extremes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Increasing frequency and severity of winter storms are projected, but the impact is unknown.

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).