

# COSEWIC Assessment and Status Report

on the

## **Butternut** *Juglans cinerea*

in Canada



**ENDANGERED**  
2017

**COSEWIC**  
Committee on the Status  
of Endangered Wildlife  
in Canada



**COSEPAC**  
Comité sur la situation  
des espèces en péril  
au Canada

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

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Nielsen, C., M. Cherry, B. Boysen, A. Hopkin, J. McLaughlin, T. Beardmore. 2003. COSEWIC status report on the butternut *Juglans cinerea* in Canada in COSEWIC assessment and status report on the butternut *Juglans cinerea* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-32 pp.

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## COSEWIC Assessment Summary

### Assessment Summary – April 2017

**Common name**

Butternut

**Scientific name**

*Juglans cinerea*

**Status**

Endangered

**Reason for designation**

This widespread early-successional tree of the Eastern Deciduous Forest occurs throughout southern Ontario and Québec, and locally in New Brunswick. The species was formerly a significant source of wood for cabinetry and instrument making and continues to hold cultural significance for some Indigenous communities in eastern Canada. The fungal disease Butternut Canker has infected almost all Canadian trees, is causing rapid mortality, and is projected to cause a near 100% decline from the pre-canker population of this species within one generation. There is evidence that some trees may be showing resistance. Ornamental introductions in Manitoba, Nova Scotia, and Prince Edward Island are not included in the assessment.

**Occurrence**

Ontario, Quebec, New Brunswick

**Status history**

Designated Endangered in November 2003. Status re-examined and confirmed in April 2017.



## COSEWIC Executive Summary

### Butternut *Juglans cinerea*

#### Wildlife Species Description and Significance

Butternut (*Juglans cinerea*) is a medium to large, deciduous tree of the walnut family reaching a height of up to 30 m. Its leaves are densely hairy, alternate, and composed of 11-17 pinnately-arranged, stalkless leaflets. The twigs are stout and hairy with a central pith divided into chambers. The Butternut fruit is a sticky-hairy, egg-shaped husk enclosing a single two-chambered nut within a hard, jagged-ridged shell.

Butternut is one of only two walnut species native to Canada, where it is at the northern limit of its native global distribution. The New Brunswick subpopulation is an outlier with noteworthy genetic divergence from the species elsewhere. The species is prized for its wood and edible nuts and was an important source of food and medicine for First Nations people. Butternut supports numerous specialist insect species, including the weevil *Eubalus parochus* and the metallic wood-boring beetle *Agilus juglandis*, possible Butternut-obligate species that may be threatened in Canada by Butternut decline.

#### Distribution

Butternut occurs across much of the central and eastern United States and small portions of southeastern Canada, occurring south to Arkansas, Mississippi, Alabama and Georgia. Within this latitudinal range, the species occurs in all states west to Minnesota, Iowa and Missouri. Butternut's native Canadian range is restricted to southern Ontario and Quebec (primarily south of the area bounded by Georgian Bay, the Ottawa Valley and the Quebec City region), and western and southern portions of New Brunswick.

#### Habitat

Butternut occurs primarily in neutral to calcareous soils of pH 5.5 to 8, often in regions with underlying limestone, and is generally absent from acidic regions. It tends to reach greatest abundance in rich well-drained mesic loams in floodplains, streambanks, terraces and ravine slopes, but can occur in a wide range of other situations. In closed-canopy stands, it must be in the overstory to thrive. Seedling establishment, growth and survival to maturity are most frequent in stand openings, riparian zones and forest edges.

## Biology

Butternut is a shade-intolerant deciduous tree that rarely lives more than 100 years. It flowers from April to June with separate male and female flowers on the same tree maturing at different times to encourage out-crossing. It is wind-pollinated and can hybridize with Japanese, English, Little and Manchurian walnuts. The fruit matures in September and October in the year of pollination. Seed bearing starts about age 20 and peaks at age 30 to 60. Generation time is estimated at 45 years, the median of this range. Good seed crops occur irregularly with light crops in intervening years. The seeds typically germinate the spring following seed fall and do not survive more than 2 years in the soil. Younger Butternut is capable of vegetative propagation from stump sprouting. Seed dispersal over land is primarily animal-mediated, and seeds may travel long distances by water flow. Pollen may be disseminated over distances exceeding 1 km.

## Population Sizes and Trends

Population size is not well documented. Remaining occurrences are still very incompletely documented and it is unclear how many of the 863 occurrences compiled by Canadian conservation data centres are still extant. Experts estimate that from tens of thousands to 100,000+ live trees remain in Ontario and Quebec and thousands to 10,000+ are in New Brunswick, but numbers are declining rapidly. Monitoring data from 1,221 trees in 60 sites across the Ontario range show 99.7% Butternut Canker infection rate, 5.43% annualized mortality from 2008 to 2014-2015, limited seedling recruitment and almost no recruitment into mature age classes. Canker infection in Quebec is also almost complete and mortality is significant. In New Brunswick, the last region reached by the disease, canker infection was 70% in 2013-2014 and dead trees are now common. Population decline from pre-canker levels is probably already well over 50%. The well documented (but single time interval) decline rate in Ontario translates to 91% loss from current levels in one generation and 100% in just short of two generations. Population declines have been estimated to exceed 90% in Michigan, Wisconsin and the southeast.

## Threats and Limiting Factors

The foremost threat is Butternut Canker, a lethal disease caused by the fungal pathogen *Ophiognomonia clavigignenti-juglandacearum*, thought to be introduced in North America, likely from Asia. Butternut Canker kills trees of all ages. Saplings are often quickly killed, while mature trees may survive up to 30 years before dying from severe crown loss and girdling by coalescing stem cankers. Seeds from infected trees can be internally infected, and recruitment into mature age classes may have nearly ceased in Canada.

In Canada, Butternut Canker was first detected in Quebec in 1990, Ontario in 1991 (where it was present by 1972 based on canker age) and New Brunswick in 1997. It now occurs throughout Butternut's native range, affecting nearly all trees in Ontario and Quebec and 70+% of trees in New Brunswick. Putatively tolerant trees are rare, genetically-based long-term disease tolerance is not well demonstrated anywhere, and some observed tolerance is associated with hybridization with the exotic Japanese Walnut.

Additional threats to Butternut include wood harvesting, forest conversion to other uses, and hybridization with Japanese Walnut. Naturally low genetic diversity may be a limiting factor.

### **Protection, Status and Ranks**

Butternut was initially assessed as Endangered by COSEWIC in 2003. It is presently listed as federally Endangered and protected under Schedule 1 of the *Species at Risk Act*. It is protected under the provincial *Endangered Species Act* in Ontario, and it is listed under the *New Brunswick Species at Risk Act* but with no prohibitions in place. It is not protected through provincial legislation in Quebec. Butternut is globally ranked as Apparently Secure (G4) and nationally ranked as Vulnerable in the United States (N3N4) and Imperilled to Vulnerable (N2N3) in Canada, though these ranks are outdated and do not account for current knowledge of Butternut Canker. It is Imperilled in Quebec (S2) and Ontario (S2?) and Critically Imperilled (S1) in New Brunswick.

## TECHNICAL SUMMARY

*Juglans cinerea*

Butternut

Noyer cendré

Range of occurrence in Canada (province/territory/ocean): Ontario, Quebec, New Brunswick

### Demographic Information

|  |  |
|--|--|
| Generation time ( <i>average age of parents in the population</i> )  | 45 years; Estimate is the median of the published peak reproductive age of 30 to 60. Following COSEWIC / IUCN guidelines, no adjustment is made for reduced longevity caused by Butternut Canker   |
| Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?   | Yes – observed and projected declines primarily from Butternut Canker, also from land development  |
| Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]  | 90+% over 2 generations (90 years) based on the known ON and QC prevalence of, and mortality from, Butternut Canker (extirpation predicted 84 years into future based on documented ON mortality rate), and knowledge of US mortality rates.   |
| [Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].  | Likely well over 50% decline in past three generations (135 years) based on documented rates of decline, the time since arrival and prevalence of Butternut Canker, and knowledge of US mortality and declines.  |
| [Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].   | 90+% decline projected in 3 generations (135 years) based on the known ON and QC prevalence of, and mortality from, Butternut Canker, and knowledge of US mortality and declines.  |
| 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.<br>* 20+ year old canker detected in 1992 in southern Ontario | 90+% decline projected from current levels within one generation (45 years) into the future with extirpation ~84 years into the future, based on documented rates of decline and knowledge of US mortality and declines. Inclusion of estimated decline since arrival of Butternut Canker (~1972*, about one generation ago) would greatly increase total decline. |
| Are the causes of the decline a. clearly reversible and b. understood and c. ceased?   | a. No<br>b. Yes<br>c. No   |
| Are there extreme fluctuations in number of mature individuals?  | No   |

### Extent and Occupancy Information

|                                |  |
|--------------------------------|--|
| Estimated extent of occurrence | 266,920 km <sup>2</sup> (if based exclusively on definitely native occurrences)<br>399,440 km <sup>2</sup> (if all observation records are considered) |
|--------------------------------|--|

|   |  |
|---|--|
| Index of area of occupancy (IAO)<br>(Always report 2x2 grid value).   | Unknown. Less than 159,700 km <sup>2</sup> (total area of grid squares intersected by core Canadian range, rounded to nearest 100 km <sup>2</sup> ).   |
| Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse? | a. No<br>b. No   |
| Number of “locations”* (use plausible range to reflect uncertainty if appropriate)  | 1 (all occurrences of the species are affected by Butternut Canker with no evidence of substantial variation in how the disease will proceed, and are therefore considered as a single location)   |
| Is there an [observed, inferred, or projected] decline in extent of occurrence?   | Yes – Projected loss of small peripheral occurrences based on documented and anticipated widespread major declines. Some loss has likely already occurred.   |
| Is there an [observed, inferred, or projected] decline in index of area of occupancy?   | Yes (loss from sparsely occupied 2 x 2 km squares is inferred based on ~90% inferred population loss in southwestern Ontario (see <b>Fluctuations and Trends</b> , re: Cambridge District), and major declines throughout range. Loss is projected to continue based on documented rates of infection and mortality. |
| Is there an [observed, inferred, or projected] decline in number of subpopulations?   | Yes (observed, inferred and projected losses). Local losses observed (CDC extirpated sites and other observations). Losses inferred based on known major declines throughout range. Losses projected based on documented rates of infection and mortality.   |
| Is there an [observed, inferred, or projected] decline in number of “locations”**?  | No. All subpopulations are considered one location because all are subject to Butternut Canker.  |
| Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?   | Yes (Observed and inferred decline in area, extent and quality with forest, old field and hedgerow loss to a large range of development)   |
| Are there extreme fluctuations in number of subpopulations?   | No   |
| Are there extreme fluctuations in number of “locations”**?  | No. All subpopulations are considered one location because all are subject to Butternut Canker.  |
| Are there extreme fluctuations in extent of occurrence?   | No   |
| Are there extreme fluctuations in index of area of occupancy?   | No   |

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



**Number of Mature Individuals (in each subpopulation)**

| Subpopulations (give plausible ranges)  | N Mature Individuals  |
|---|---|
| <p><b><i>Known occurrences in both Ontario and Quebec are not comprehensively compiled, and many undocumented occurrences exist.</i></b></p> <p>About 1,300 occurrences documented (excluding historical occurrences and using a 1 km separation distance), but this may include many occurrences now extirpated.</p> <p>Ontario<br/>About 800 sites documented. 346 occurrences ranked as Verified Extant (observed in past 20 years, but not necessarily actually still extant because of canker mortality), 61 ranked as Historical (not observed in over 20 years, but may still be present) and one considered Extirpated.</p> <p>Quebec<br/>At least 378 occurrences documented, but some portion of these are likely now extirpated by canker.</p> <p>New Brunswick<br/>139 occurrences documented. Many undocumented occurrences exist.</p> | <p>Not known precisely, but experts estimate tens of thousands to 100,000+ live trees in Ontario and Quebec, and thousands to 10,000+ in New Brunswick.</p> |

**Quantitative Analysis**

|   |                                      |
|---|--------------------------------------|
| <p>Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].</p> | <p>No quantitative analysis done</p> |
|---|--------------------------------------|

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

|  |
|--|
| <p>Was a threats calculator completed for this species? Yes, see Appendix 1</p> <p>i. Invasive Non-native Pathogen: Butternut Canker<br/>           ii. Habitat Conversion<br/>           iii. Logging and Wood Harvesting<br/>           iv. Introduced Genetic Material: Hybridization with Japanese Walnut</p> <p><u>Less Significant Threats (Unknown rating)</u></p> <p>v. Problematic Native Species: White-tailed Deer<br/>           vi. Climate Change</p> <p>What additional limiting factors are relevant?</p> <p>i. Low Genetic Diversity<br/>           ii. High Levels of Seed Predation</p> |
|--|

### Rescue Effect (immigration from outside Canada)

|  |   |
|--|---|
| Status of outside population(s) most likely to provide immigrants to Canada. | Michigan (S3), Ohio (S4), Pennsylvania (S4), New York (S4), Vermont (S3), New Hampshire (S3), Maine (S3). These ranks do not reflect declines and threats from Butternut Canker, which are significant in all above jurisdictions.                                  |
| Is immigration known or possible?  | Yes, not known but possible   |
| Would immigrants be adapted to survive in Canada?                            | No – no resistance to Butternut Canker known in United States, though adjacent American occurrences would presumably be suited to Canadian environmental conditions   |
| Is there sufficient habitat for immigrants in Canada?                        | Yes   |
| Are conditions deteriorating in Canada?+                                     | Yes   |
| Are conditions for the source population deteriorating?+                     | Yes   |
| Is the Canadian population considered to be a sink?+                         | No. The population is not dependent upon or significantly influenced by immigration from outside Canada   |
| Is rescue from outside populations likely?                                   | No. Limited rescue potential through water-borne or animal dispersal. Potential source populations are in poor health due to Butternut Canker and are unlikely to provide a meaningful source of uninfected or resistant seeds. Natural dispersal potential is low. |

### Data Sensitive Species

Is this a data sensitive species? No

### Status

COSEWIC: Designated Endangered in November 2003. Status re-examined and confirmed in April 2017.

### Status and Reasons for Designation:

|   |  |
|---|--|
| <b>Status:</b><br>Endangered  | <b>Alpha-numeric codes:</b><br>A2ae+3e+4ae |
| <b>Reasons for designation:</b><br>This widespread early-successional tree of the Eastern Deciduous Forest occurs throughout southern Ontario and Quebec, and locally in New Brunswick. The species was formerly a significant source of wood for cabinetry and instrument making and continues to hold cultural significance for some Indigenous communities in eastern Canada. The fungal disease Butternut Canker has infected almost all Canadian trees, is causing rapid mortality, and is projected to cause a near 100% decline from the pre-canker population of this species within one generation. There is evidence that some trees may be showing resistance. Ornamental introductions in Manitoba, Nova Scotia, and Prince Edward Island are not included in the assessment. |  |

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

### **Applicability of Criteria**

|  |
|--|
| Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2ae+3e+4ae. Reduction over past three generations estimated at over 50 percent. Ongoing declines due to Butternut Canker projected to cause near 100% decline from pre-canker population within one generation. |
|--|

|   |
|---|
| Criterion B (Small Distribution Range and Decline or Fluctuation): Not met. |
|---|

|  |
|--|
| Criterion C (Small and Declining Number of Mature Individuals): Not met. |
|--|

|   |
|---|
| Criterion D (Very Small or Restricted Population): Not met. |
|---|

|   |
|---|
| Criterion E (Quantitative Analysis): No data to conduct analysis. |
|---|

## PREFACE

Butternut (*Juglans cinerea*) was initially assessed by COSEWIC in 2003 (COSEWIC 2003) and subsequently listed as Endangered under SARA. Since the 2003 report, considerable new occurrence data have been collected. Conservation data centres in Ontario, Quebec and New Brunswick have compiled over 7,600 observation records for the species, representing 863 separate occurrences. These data allow for better assessments of distribution, extent of occurrence, and area of occupancy. The COSEWIC (2003) Canadian population estimate of 13,600, noted in the report as being very conservative, is now known to have been a substantial underestimate, and an inaccurate citation of a value that was never intended as a comprehensive population estimate.

Butternut Canker, a fungal disease (caused by the fungal pathogen *Ophiognomonia clavigignenti-juglandacearum*) representing the primary threat to Butternut's survival, has spread significantly over the last decade to occupy all of Butternut's Canadian range. Reliable data on the disease's prevalence has shown 90-100% infection rates in Ontario and Quebec and 70% infection rates in New Brunswick. The Ontario Ministry of Natural Resources and Forestry established 60 monitoring plots in 2006 across the southern Ontario range, on which 100% canker infection (excluding one hybrid with Japanese Walnut—*Juglans ailantifolia*) and 39% mortality was documented from 2008 to 2014-2015 on the 1,221 trees initially assessed. The Forest Gene Conservation Association (FGCA) has conducted extensive fieldwork relating to Butternut recovery from 1995-2017 and continues to expand its Butternut recovery work. The FGCA has searched for putative tolerance to Butternut Canker, and has archived the genetic material of over 70 potentially tolerant, DNA-confirmed, pure Butternut trees since 2008 by grafting them onto canker-resistant Black Walnut (*Juglans nigra*) root stock. The grafted trees are maintained in managed, protected seed orchards with the goal to conserve the genetic diversity of Ontario subpopulations and produce seed for reintroduction. Over 50 additional trees await grafting and many others are expected to be found.

Research and propagation efforts elsewhere have shown little evidence of genetically-based disease resistance or tolerance in genetically pure Butternut, and have discovered that hybridization with Japanese Walnut is frequent in wild subpopulations (though generally infrequent in Canada, <10% of trees) and is often the source of some disease resistance.

Recent research into the genetic diversity of Butternut has suggested that New Brunswick occurrences exhibit a higher level of divergence than any other sampled subpopulations in the U.S. However, comparison with Ontario subpopulations does not demonstrate major divergence and the species occurs on similar habitat throughout its range. As such, the species is treated as a single designatable unit in Canada.



## 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 (2017)

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

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

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

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



Environment and  
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Canadian Wildlife Service

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Canada

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

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on the

## **Butternut** *Juglans cinerea*

**in Canada**

2017

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## WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

### Name and Classification

Species: *Juglans cinerea* L.

Synonym: *Wallia cinerea* (L.) Alef.

Common names: English: Butternut, American Butternut, White Walnut, Oilnut, Lemonnut

French: Noyer cendré, Arbre à noix longues, Noix longues, Noix tendre

Mohawk: Akiehwa'ta

Maliseet: Pokanewimus

Mi'kmaq: Epganmosi

Tribe: Juglandae

Family: Juglandaceae

Order: Fagales

Superorder: Rosanae

Class: Magnoliopsida

Subdivision: Spermatophytina

Division: Tracheophyta

### Morphological Description

Butternut (*Juglans cinerea*) is a relatively short-lived, medium to large, early-successional, deciduous tree (Figure 1). Although it can reach 30 m (Rink 1990; Whittemore and Stone 1997), average mature individuals are more typically 12 to 18 m high with trunk diameters of 30 to 60 cm at breast height (Clark 1965). The trunk, which is often divided (Farrar 1995), branches into a broad, open crown up to 15 m wide in open conditions (Woeste and Pijut 2009). The light grey or grey-brown bark is smooth on young trees, gradually becoming shallowly to deeply fissured. Leaves are 30 to 60 cm long, composed of 11 to 17 ovate leaflets each 5 to 11 cm long (Figure 2). Leaves, branchlets and fruit are densely sticky-hairy, especially when young. Twigs are stout (to almost 1 cm wide near the tips) with a chambered dark brown pith and conspicuous large leaf scars. Butternut is monoecious, with drooping male catkins occurring on second-year twigs and inconspicuous female flowers in groups of 2 to 8 at branch tips. The fruit is a two-chambered nut with a hard jagged-ridged shell enclosed within a sticky-pubescent egg-shaped husk 5 to 10 cm long. The common name "White Walnut" refers to the species' light

coloured wood. See Farrar (1995), Whittemore and Stone (1997), and Gleason and Cronquist (1991) for more complete technical descriptions.

Butternut is similar to Black Walnut (*Juglans nigra*) which is native in southwestern Ontario and widely planted and occasionally escaped elsewhere in Butternut's Canadian range. In contrast to Butternut's strongly pubescent leaves with large terminal leaflets, pubescent twigs, pubescent leaf scars, dark brown pith and hairy egg-shaped fruits with jagged-ridged inner shells, Black Walnut has smooth or only slightly hairy leaves and twigs, terminal leaflets that are absent or noticeably smaller than the lateral leaflets, hairless leaf scars, orange-yellow pith and nearly hairless globose fruits with inner shells bearing rounded ridges (Farrar 1995; Whittemore and Stone 1997; COSEWIC 2003). Distinctions between Butternut and its hybrids with non-native walnut crosses are given in Table 1. Catling and Small (2001) provide a complete key to all native and introduced walnut species and hybrids occurring in Canada.



Figure 1. Butternut (*Juglans cinerea*) at edge of floodplain meadow, Nashwaak River, New Brunswick. Photo: David Mazerolle, AC CDC.



Figure 2. Compound leaf and bark of Butternut (*Juglans cinerea*) at Plymouth, New Brunswick. Photo: David Mazerolle, AC CDC.

**Table 1. Summary of characteristics distinguishing Butternut from hybrids of Butternut and non-native species (most frequently Japanese Walnut). Contents are adapted from Woeste *et al.* (2009).**

| <b>Character</b>          | <b>Butternut</b>  | <b>Hybrid Butternut</b>   |
|---------------------------|---|---|
| Current-year stem         | Olive green, changing to red-brown near terminal buds, glossy, and with few hairs except immediately beneath terminal buds  | Bright green to copper brown or tan, changing to pale green near terminal bud, often densely covered with russet or tan hairs, especially near terminal buds  |
| Terminal bud (1-yr twigs) | Beige in colour, longer and narrower than in hybrids, with outer fleshy scales more tightly compact   | Pale green to tan or yellowish in colour, wider and squatter than in <i>J. cinerea</i> ; outer fleshy scales more divergent than Butternut and often deciduous  |
| Lateral bud (1-yr twigs)  | Vegetative buds are elongated (sometimes stalked) and somewhat angular, creamy white to beige in colour   | Vegetative buds are rounded and green to greenish brown in colour   |
| Lenticels (1-yr twigs)    | Small, round, abundant, evenly distributed, and sometimes elongating horizontally across the branch (perpendicular to the stem axis)  | Large, often elongating laterally down the branch (parallel to the stem axis) on 1-yr wood, patchy distribution; on 3 and 4-yr wood, lenticels often form a diamond pattern as they become stretched both transversely and longitudinally |
| Leaf scar (1-yr twigs)    | Top edge almost always straight or slightly convex; scar usually compact  | Top edge almost always notched; often with large, exaggerated lobes   |
| Pith (1-yr twigs)         | Dark brown  | Dark brown, medium brown or even light brown  |
| Bark (mature tree)        | Varies from light grey and platy to dark grey and diamond patterned in mature trees; in older trees, fissures between bark ridges may be shallow or deep but are consistently dark grey in colour | Silvery or light grey, rarely darker; fissures between bark ridges moderate to shallow in depth and often tan to pinkish tan in colour  |
| Leaf senescence           | Leaves yellow and brown by early mid-autumn, dehiscing in early to mid-autumn   | Leaves often green until late autumn, dehiscing in late autumn or may freeze green on the tree  |
| Catkins                   | 5-12 cm in length at peak pollen shed   | 13-26 cm in length at peak pollen shed  |
| Nut Clusters              | One or two nuts in most clusters, sometimes three to five, rarely more  | Usually three to five per cluster, sometimes as many as seven   |

## Taxonomy

Butternut has always been considered a distinct species since its description by Linnaeus in 1753.

*Juglans* L. is a principally New World genus of about 21 extant species occurring in North America, South America, the West Indies, southeastern Europe, mainland Asia, and Japan (Manning 1978; Aradhya *et al.* 2005, 2006). The most recent genetic analyses have placed Butternut with other North American *Juglans* in section Rhysocaryon (Aradhya *et al.* 2006, 2007; Zhao and Woeste 2010), rather than with Asian species in section Cardiocaryon (Fjellstrom and Parfitt 1995) or in its own section Trachycaryon (Manning 1978; Ostry and Pijut 2000; Aradhya *et al.* 2006).

## Population Spatial Structure and Variability

Several recent studies have described phylogeographic structure within the native range of Butternut. Laricchia *et al.* (2015) investigated chloroplast genetic diversity throughout its range (14 study sites, eight regions of the chloroplast genome, 197 individuals sampled) and found ten chloroplast haplotypes. The three most common haplotypes were not closely related to one another and were each restricted to a western, southern or eastern portion of the range, suggesting separate post-glacial migration pathways. Of 51 Canadian individuals sampled (14 from one Ontario site and 37 from three New Brunswick sites), 50 shared the most common eastern haplotype and one, from Keswick, New Brunswick on the Saint John River, exhibited a highly divergent haplotype found nowhere else, providing no evidence that New Brunswick trees are a uniformly divergent population.

Within-population genetic diversity in Butternut is generally inversely correlated with latitude, with subpopulations north of the last glacial maximum exhibiting much lower levels of heterozygosity, isozyme diversity and nuclear microsatellite polymorphisms (Morin *et al.* 2000; Ross-Davis *et al.* 2008a; Hoban *et al.* 2010; Laricchia *et al.* 2015; Boraks and Broders 2016). In a range-wide study, Hoban *et al.* (2010) conducted Bayesian cluster analysis and a principal components analysis of pairwise  $F_{ST}$  (a fixation index, quantifying genetic differentiation between subpopulations), finding evidence of lower gene flow and higher levels of population structure and genetic drift in northern peripheral subpopulations. Lower diversity and higher differentiation at the northern range edge are most likely a result of founder effects during range expansion following glacial retreat (Hoban *et al.* 2010; Laricchia *et al.* 2015).

Boraks and Broders (2016) investigated variation in six neutral microsatellite markers in 206 individuals from 16 subpopulations in New York, Vermont, New Hampshire and southern Maine, including two sites along the Quebec border. They found weak subpopulation differentiation ( $F_{ST}=0.084$ ), an absence of regional genetic structure and no sign of a recent bottleneck. Population statistics and Bayesian analysis indicated significant historical gene flow among their subpopulations and they concluded that surviving Butternut in the northeast United States could be considered a single broadly distributed population, though they noted that could change rapidly because of fragmentation caused by mortality. They also found significantly greater allele differentiation in riparian subpopulations compared to upland ones.

Hoban *et al.* (2010) described, using microsatellite markers, some genetic divergence in three New Brunswick subpopulations, in comparison with two in Ontario and one in Quebec, though it is difficult to assess the significance of the differences with such a limited sample size (Beardmore pers. comm. 2016). In contrast with the Laricchia *et al.* (2015) study above which found limited genetic difference between New Brunswick and Ontario-Quebec individuals, there is good evidence that New Brunswick subpopulations are distinct from those in the United States (Hoban *et al.* 2010, see Figure 3; Romero-Severson 2012; Hoban pers. comm. 2015). Jeanne Romero-Severson of Notre Dame University (2012) conducted a range-wide assessment of 39 subpopulations including 13 New Brunswick and 26 United States subpopulations, using 11 gSSR (genomic simple sequence repeat) markers, 10 developed from Butternut (Hoban *et al.* 2008) and one from Black Walnut (Woeste *et al.* 2002). Her results show that New Brunswick has at least two unique gene pools (Romero-Severson 2012). Principal component analysis showed a difference between New Brunswick Butternut and the other subpopulations from across the range in the United States greater than that between any other non-New Brunswick subpopulations, and differences among New Brunswick subpopulations (13 subpopulations; of 78 pairwise  $F_{ST}$  values, eight were less than 0.03, 35 were 0.03 to 0.049, and 35 were 0.05 or greater, of which eight were 0.08 to 0.099). This differentiation suggests genetic isolation over a long period of time, possibly via persistence in an unknown northern refugium different from the rest of the species (Beardmore pers. comm. 2015; Hoban pers. comm. 2015), as has also been speculated for genetically distinct populations of Black Spruce (*Picea mariana*), Red Pine (*Pinus resinosa*) and Jack Pine (*Pinus banksiana*) elsewhere in Atlantic Canada (Jaramillo-Correa *et al.* 2004; Boys *et al.* 2005; Godbout *et al.* 2010).

Additionally, during 2015-16, as part of an ongoing study, the Canadian Forest Service and Jeanne Romero-Severson have evaluated 425 trees in 25 subpopulations throughout Butternut's range in New Brunswick for general health and genetic diversity (Beardmore pers. comm. 2016). Eleven gSSR markers and two chloroplast CAPS (cleaved amplified polymorphic sequences) markers were used to evaluate the genetic diversity of New Brunswick Butternuts relative to the rest of the native range in the US and to detect evidence of Japanese Walnut (*Juglans ailantifolia*) ancestry. Their results further supported the Romero-Severson (2012) finding that New Brunswick Butternuts are highly divergent from those in the United States (Beardmore pers. comm. 2016), and seven samples were identified as Japanese Walnuts, mostly from anthropogenic sites, but including one from a remote and undisturbed site in which pure Japanese Walnut would be improbable<sup>1</sup>. Six samples were identified as introgressed hybrids.

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<sup>1</sup> This site, Butternut Island in the Little River, Sunbury County, New Brunswick, is remote (5 km to the nearest residence, 9 km to the nearest settlement), is unlikely to have ever been farmed and supports a completely native community of rich floodplain herbs typical of native Butternut habitat (Blaney pers. obs. 2002). The genetic identification of trees here as Japanese Walnut and hybrids seems questionable.

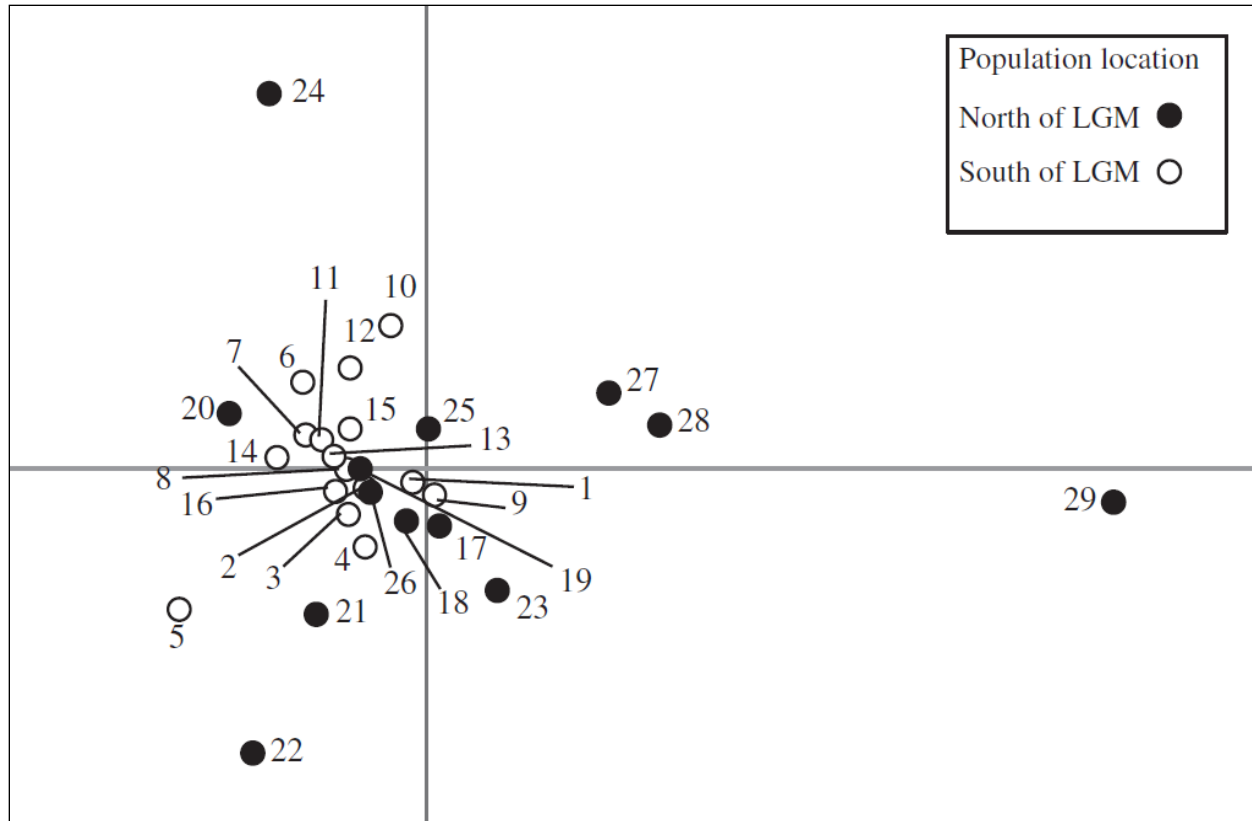


Figure 3. Principal component analysis based on  $F_{ST}$ , illustrating levels of genetic divergence within the global range of Butternut. Populations labelled 27, 28 and 29 are located in New Brunswick, population 24 is situated in Quebec and populations labelled 25 and 26 are situated in Ontario. LGM refers to the ice limit at the last glacial maximum. From Hoban *et al.* (2010), with permission.

## Designatable Units

There is some evidence of the discreteness of the Ontario/Quebec and New Brunswick occurrences of Butternut; however, the significance is questionable.

As described in **Population Spatial Structure and Variability**, there is limited information on the divergence of New Brunswick Butternut from subpopulations in Ontario and Quebec, but significant levels of divergence in New Brunswick compared with United States subpopulations, suggesting origin from different glacial refugia and perhaps separation predating glaciation (Severson-Romero 2012; Hoban pers. comm. 2015).



There may be a modest disjunction between the Butternut occurrences that straddle the New Brunswick – Maine border in the vicinity of Woodstock, New Brunswick and Houlton, Maine, and the rest of its range. Butternut is reported from all Maine counties in Kartesz (2015); however, some of that distribution is probably based on planted or naturalized occurrences, as much of the northern portion of Maine lacks native subpopulations (Cameron pers. comm. 2015; Haines pers. comm. 2016). Apparently native herbarium records extend northeast in Maine at least to the Bangor area about 180 km southeast of the nearest New Brunswick records (Consortium of Northeastern Herbaria 2016). The actual disjunction may be less than this. Arthur Haines (pers. comm. 2016), author of *Flora Novae Angliae* (Haines 2013) suggests that Butternut was “almost without a doubt” present historically on the Penobscot River (extending within about 75 km of known occurrences along the Maine-New Brunswick border) based on habitat and the fact that there is a Penobscot word for the species (pakónosi). He also notes that the Passamaquoddy also had this word (pokanimùs for the tree and pokan for the nut), suggesting the possibility of occurrence into that nation’s territory in southeastern-most Maine near the New Brunswick border. Suitable habitat for Butternut exists between the Penobscot River and known New Brunswick occurrences in the Mattawamkeag and the upper Meduxnekeag watersheds and undocumented subpopulations could be present there, meaning that at least historically there may not have been disjunctions of Butternut range in Maine and New Brunswick exceeding 50 km. Additionally, there are undoubtedly some planted occurrences in the zone between southern Maine and New Brunswick.

New Brunswick occurrences are clearly separated by about 200 km between the Grand Falls, New Brunswick and city of Québec areas. This distance is likely beyond the typical range of pollen movement (see **Dispersal and Migration**) and distances are large enough that there is unlikely to be sufficient dispersal between Ontario/Quebec and New Brunswick to prevent local adaptation (COSEWIC 2014).

The New Brunswick and Ontario/Quebec occurrences of Butternut are in almost entirely separate COSEWIC National Ecological Areas (NEAs; COSEWIC 2014). The New Brunswick occurrences are in the Atlantic NEA, while the Ontario/Quebec occurrences are within the Great Lakes Plains NEA, except for very limited areas extending into the Atlantic NEA (Figure 4) in southeastern-most Quebec and into the Boreal NEA north of the Ottawa River. Because Butternut occurrence is not comprehensively databased in Quebec, there may be somewhat more occurrence outside the Great Lakes Plains NEA than is mapped in Figure 4.

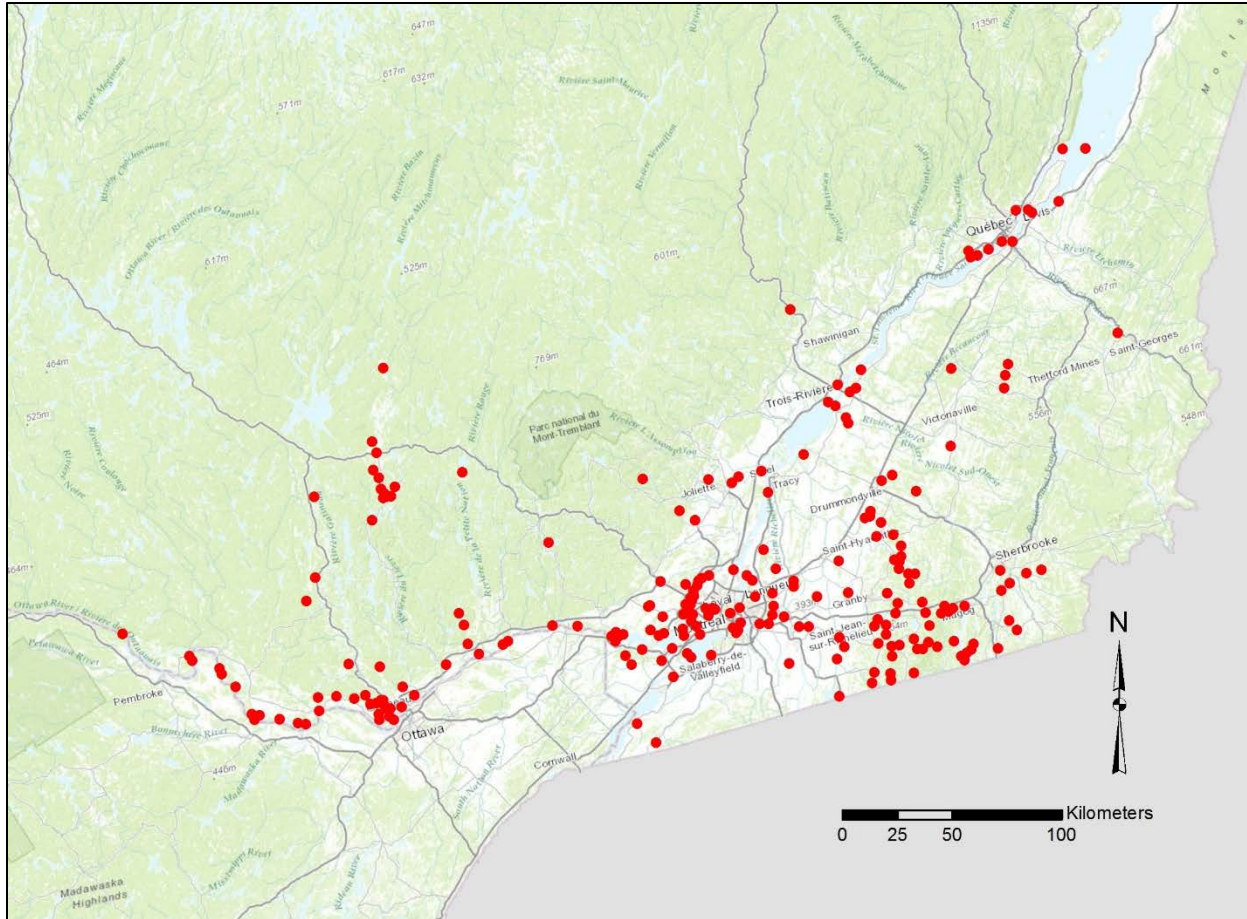


Figure 4. Quebec Butternut observation records compiled in the CDPNQ database. The native origin of some outlying occurrences is uncertain. Basemap from OpenStreetMap, containing data from GeoBase, GeoGratis (Department of Natural Resources Canada), CanVec (Department of Natural Resources Canada), and StatCan (Geography Division, Statistics Canada).

The “relevance to the species” (COSEWIC 2014) of the differing eco-regions is questionable, as climate and ecological setting of occurrences (which would drive local adaptation) are very similar. The ecological settings of the New Brunswick occurrences and those in Ontario/Quebec are in predominantly deciduous forests on calcareous soils, with the associated tree and understory plant species in New Brunswick occurrences being very similar to those in Ontario/Quebec (Blaney pers. obs. 1989-2015 in Ontario and New Brunswick; Doyon *et al.* 1998). The New Brunswick subpopulations are, however, sufficiently separated that natural dispersal is unlikely to occur. Their loss would result in a significant reduction in the Canadian range, but would not produce an “extensive disjunction” (COSEWIC 2014) within the Canadian range. The evolutionary significance of the New Brunswick occurrences is harder to demonstrate. There is evidence of comparatively deep phylogenetic divergence by the standards of the species. This is, however, based on microsatellite frequency which is noted in COSEWIC (2014) as generally being insufficient to demonstrate significance because of the rapid evolution of microsatellites.

In this status report, Butternut is treated as a single designatable unit.

## Special Significance

Butternut is one of only two species of the walnut genus *Juglans* that are native to Canada. The Canadian population is at the northern and northeastern peripheries of the species' native global range. Populations at the edge of a species' geographical range often occupy less favourable habitats, exhibit lower densities, tend to be more fragmented, and are less likely to receive immigrants from other populations (Channel and Lomolino 2000). Through isolation, genetic drift and natural selection, peripheral populations can give rise to genetic, ecological and morphological divergence, increasing their conservation significance as sources of adaptive genotypes and as source populations for range recolonization or migration; they can also be important as final refuges (Lesica and Allendorf 1995; Garcia-Ramos and Kirkpatrick 1997; Gibson *et al.* 2009). Canadian Butternut subpopulations are known to exhibit significantly higher differentiation than core United States or southern peripheral subpopulations (Hoban *et al.* 2010). New Brunswick occurrences, which are isolated from the species' main native range by about 180 km, show a level of genetic differentiation far greater than that seen in any other subpopulations across the species' range (Hoban *et al.* 2010; Hoban pers. comm. 2015, see **Population Spatial Structure and Variability**). These genetically distinct occurrences may therefore be of particularly high conservation significance.

Butternut supports a wide range of insects (see **Interspecific Interactions**), many of which are specialists of walnuts, occurring on few or no other tree species. At least a few of these, most notably the weevil (*Eubalus parochus*, family Curculionidae) and the Butternut Agrilus wood-boring beetle (*Agrilus juglandis*, family Buprestidae), may be entirely dependent on Butternut (Halik and Bergdahl 2002, 2006; Anderson 2008; Paiero *et al.* 2012) and may warrant COSEWIC status assessment because of Butternut decline. In New Brunswick, the owlet moths (family Noctuidae) Gray-edged Hypena (*Hypena madefactalis*) and The Bride Underwing (*Catocala neogama*) are very rare provincially and presumed entirely dependent on Butternut (Webster *et al.* 2005; Webster pers. comm. 2016). The provincially rare Banded Hairstreak butterfly, *Satyrium calanus* (family Lycaenidae) is also primarily or exclusively reliant on Butternut as a food plant in New Brunswick (Webster pers. comm. 2016).

Butternut wood is lightweight, soft and coarse-grained. Its qualities once made it favourable for cabinetwork, interior finishing, carving, musical instruments and boats (Woeste *et al.* 2009). It does not have high economic value in Canada, but was valued in the U.S. as a timber species, although its widely-scattered growth habit within stands and relatively soft wood limit its commercial importance (Ostry and Pijut 2000). The species is also valued economically for its edible nuts (Woeste and Pijut 2009), which have a delicious buttery flavour and an oil content of up to 60% at peak ripeness (Rupp 1990). More than 70 Butternut cultivars have been described with a few genotypes exhibiting good nut qualities for commercial production (large size and ease of cracking) (Millikan *et al.* 1990; Ostry and Pijut 2000; Woeste 2004). Nut growers value Butternut as a cold-hardy, nut-producing

species. Nuts have been especially popular in New England for making maple-Butternut candy. Additionally, there are reports that Butternut trees were tapped by the pioneers and yielded an excellent syrup (Lauriault 1989), though the ratio of sap to syrup is estimated to be four times higher than that of maple trees (Rupp 1990).

Juglone, an organic compound derived from walnuts, including Butternut, is antiseptic and herbicidal with some antitumour properties reported. An animal study suggests that juglone possesses sedative activity comparable with diazepam (the prescription drug Valium; Girzu *et al.* 1998). The inner bark of the root has a mild cathartic property, and may be used as a habitual laxative, as well as for toothaches, dysentery and hepatic congestions (Lauriault 1989; Schultz 2003). The expressed oil of the nut is also said to combat tapeworms (Schultz 2003).

The First Nations of North America had many medicinal and cultural uses for Butternut (Smith 1923, 1928, 1933; Gilmore 1933; Hamel and Chiltoskey 1975; Herrick 1977; Chandler *et al.* 1979; Talalay *et al.* 1984). It was likely used by all First Nations within its Canadian range. For example, the Ojibwe (Smith 1932), Haudenosaunee (Herrick 1977), Algonquin (Black 1980), Maliseet (Mechling and Rioux 1958) and Mi'kmaq (Chandler *et al.* 1979) are reported to have used it for food, dyes and medicine. Its nuts were prized for their high nutritional value and its sap was boiled to produce syrup (Goodell 1984).

## DISTRIBUTION

### Global Range

Butternut is a widespread species found across much of the central and eastern United States and small portions of southeastern Canada. The species ranges from southern Ontario, southern Quebec and New Brunswick in the north to Arkansas, Mississippi, Alabama, and Georgia in the south (Rink 1990; Whittemore and Stone 1997; BONAP 2015). Within this latitudinal range (roughly latitudes 32° to 47°), the species occurs in all states from the Atlantic Coast west to Minnesota, Iowa and Missouri. Most of the species' range, containing the highest density of occurrences, is found in the Appalachian Region, southern Great Lakes Region, Upper Mississippi River watershed and Ohio River watershed. Disjunct occurrences are found in New Brunswick and several states at the southern limit of the species' range (BONAP 2015). The native global range of Butternut is illustrated in Figure 5.

The importance of Butternut as a source of food and medicine for Indigenous peoples is well-documented (Smith 1923; Gilmore 1933; Hamel and Chiltoskey 1975; Herrick 1977; Chandler *et al.* 1979; Talalay *et al.* 1984), and First Nations likely played a role in disseminating the species prior to European settlement (Wykoff 1991). Butternut is also frequently planted outside its native range, with 72 cultivars (65 specific, 7 hybrid) registered by the U.S. Department of Agriculture Forest Service (Woeste 2004). As a result, the boundaries of the species' natural range are difficult to accurately define.

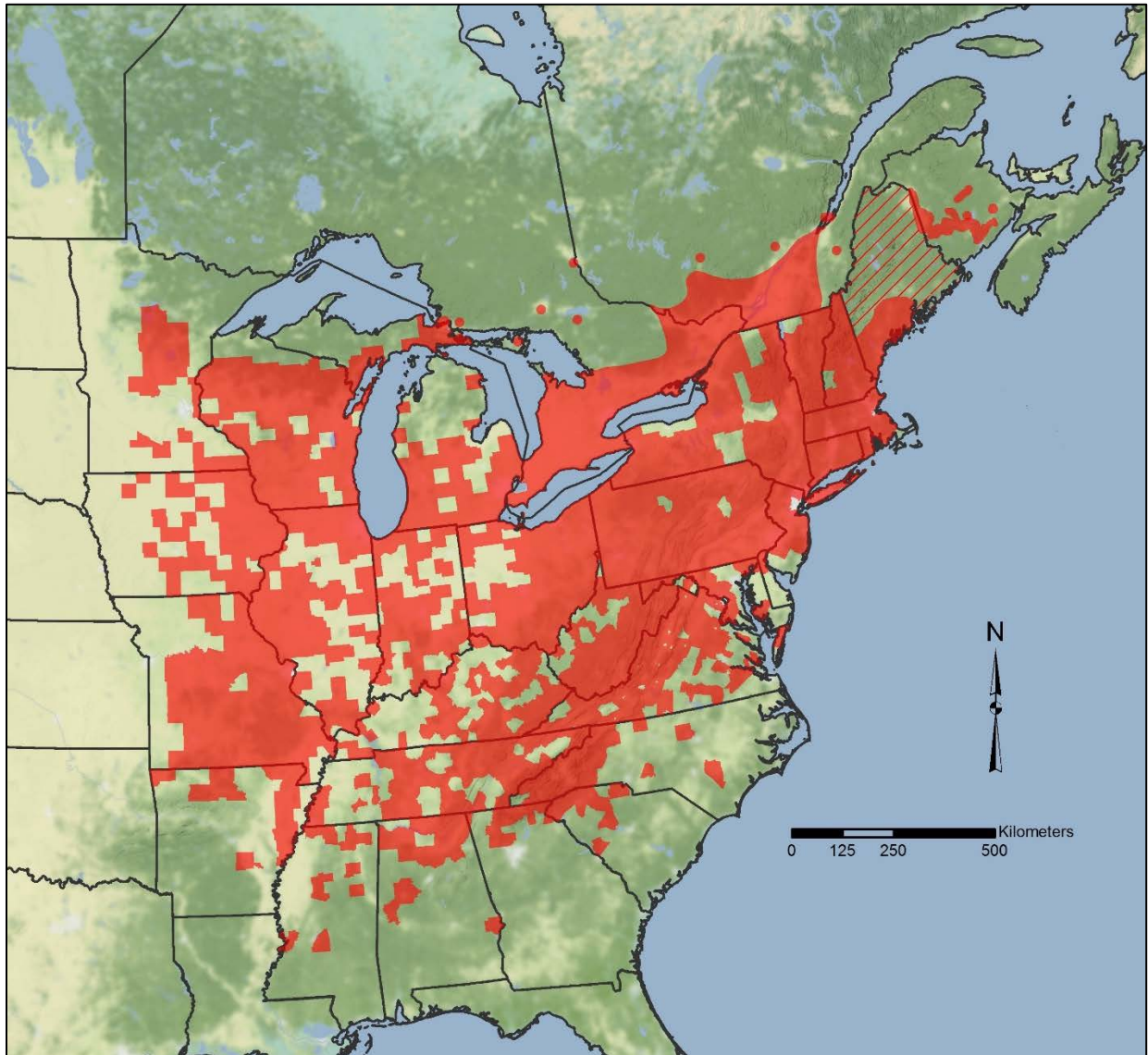


Figure 5. Global range of Butternut. Shading indicates forest cover. Canadian range is adapted from Farrar (1995) based on data from ONHIC (2015), AC CDC (2016) and CDPNQ (2015). Range in the United States is based on county-level data from BONAP (2015), except for Maine. Hatched area in Maine indicates range mapped by BONAP (2015), but distribution in northern Maine (and perhaps northern New Hampshire) counties may represent planted individuals or establishment from planted individuals outside the original native range (see discussion under Designatable Units). Maine distribution is based on Consortium of Northeast Herbaria (2016) records and Bergdahl (pers. comm. 2016). Some other disjunct peripheral occurrences, especially those in northern Ontario (see Canadian Range), may represent plantings or establishment from plantings outside the native range. Basemap from Stamen, based on OpenStreetMap data.

## Canadian Range

Butternut's native Canadian range is restricted to southern Ontario, southern Quebec, and portions of western and southern New Brunswick (Figure 6). In Ontario and Quebec, the species is limited to an approximately 1,100 km band extending from Windsor to the city of Québec and is almost entirely contained within the Great Lakes Plains National Ecological Area but also extends into the Boreal National Ecological Area (COSEWIC 2014).

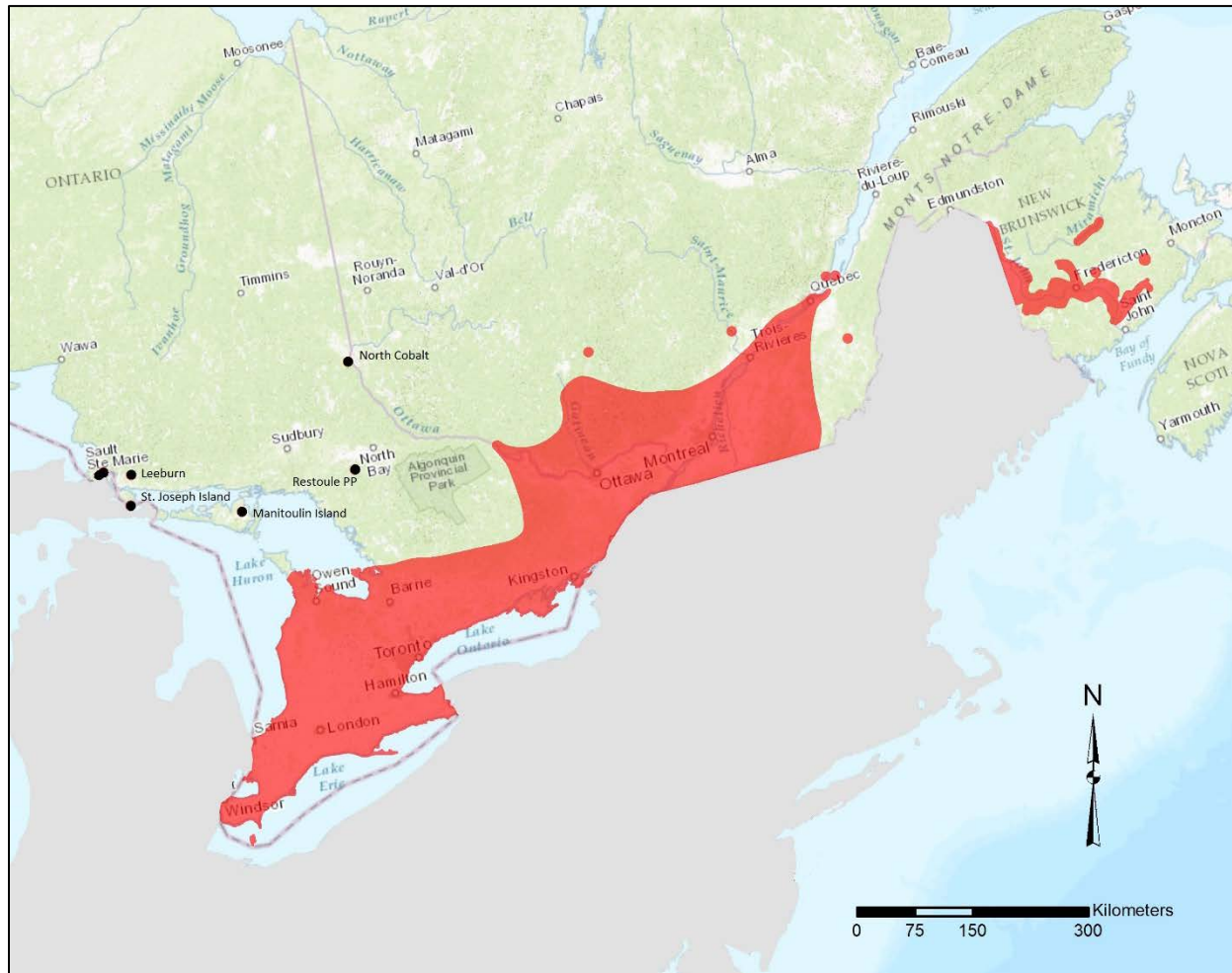


Figure 6. Canadian native range of Butternut (adapted from Farrar 1995; ONHIC 2015; AC CDC 2015; CDPNQ 2015). Black dots in Ontario are probably non-native occurrences (see Canadian Range), although the Sault Ste. Marie, Leeburn, St. Joseph Island and possibly the Manitoulin Island records might be close enough to presumed native range in adjacent Michigan (see Figure 5) that they could be considered as not extra-limital and therefore relevant for status assessment. Basemap from Stamen, based on OpenStreetMap data.

In Ontario (Figure 7), the area in which Butternut is unquestionably native extends as far north as the southern Bruce Peninsula (Bruce County) in the west and Chalk River along the Ottawa River in the east. Scattered additional occurrences are documented

further north between Sault Ste. Marie in the west eastward to North Cobalt in the upper Ottawa River watershed in the district of Timiskaming (Farrar 1995; OMNR 2011; ONHIC 2015). All of these occurrences are near human settlement (ONHIC 2015), and most or all likely represent plantings into natural or semi-natural habitat, or establishment in the wild from planted trees (Wilson pers. comm. 2016; see Figure 7). St. Joseph’s Island records likely originate with a local nursery that grows Butternut (Meades pers. comm. 2017), but regardless of origin, the Sault Ste. Marie, St. Joseph Island and Leeburn records might be argued to occur within Butternut’s natural range based on Reznicek *et al.* (2011) stating that some, if not all, Butternut occurrences in Michigan’s Upper Peninsula (immediately across the border from Sault Ste. Marie and St. Joseph Island) appear to involve native trees. Butternut was considered non-native on Manitoulin Island and was noted as commonly planted in Morton and Venn’s (1984) *The Flora of Manitoulin Island*.

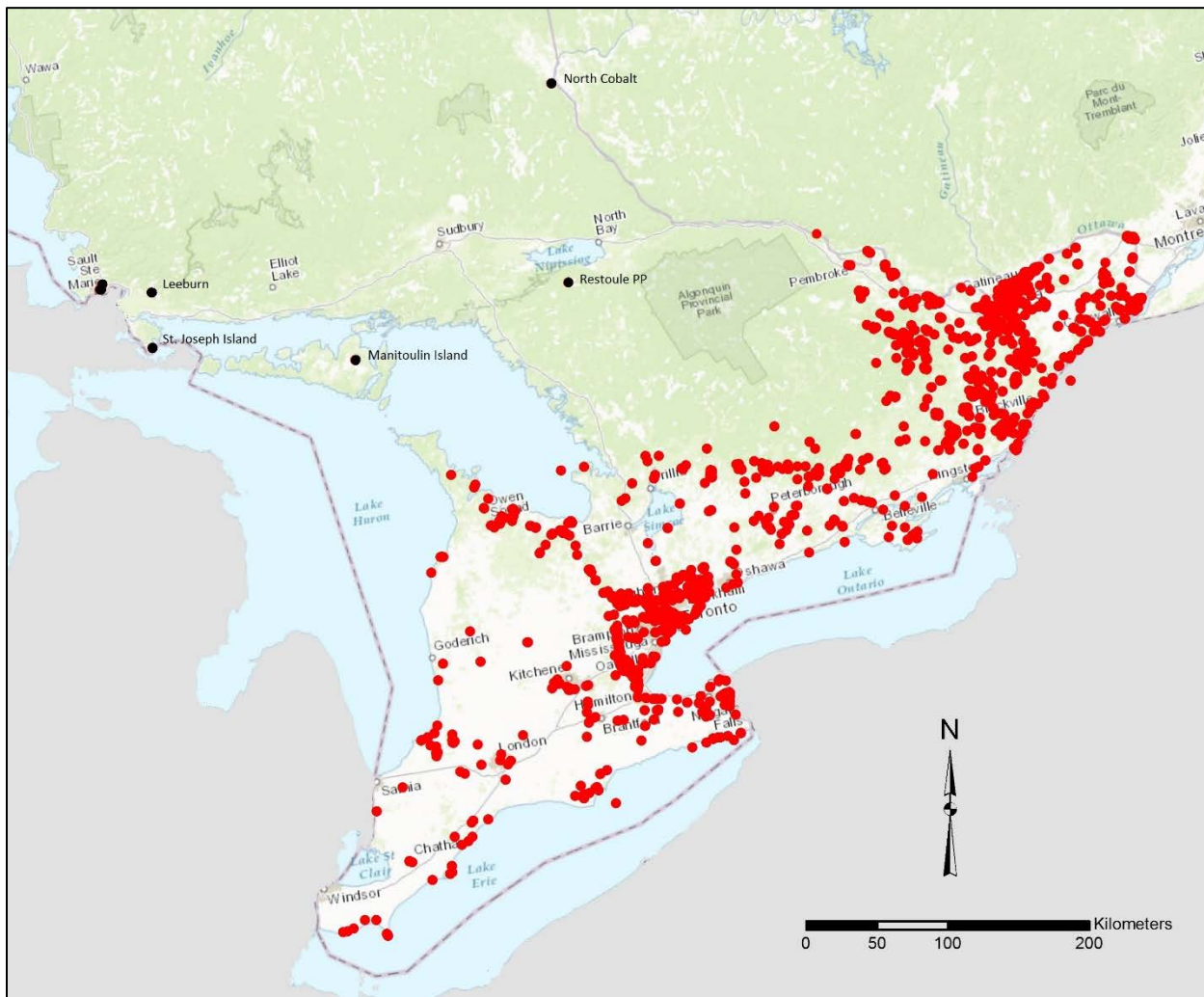


Figure 7. Ontario Butternut observation records compiled in the ONHIC database. The dataset does not contain Ontario Tree Atlas data (see Figure 8). The native origin of the outlying northern occurrences (black dots) is uncertain (see Figure 6, and **Canadian Range**). Basemap from OpenStreetMap, containing data from GeoBase, GeoGratis (Department of Natural Resources Canada), CanVec (Department of Natural Resources Canada), and StatCan (Geography Division, Statistics Canada).

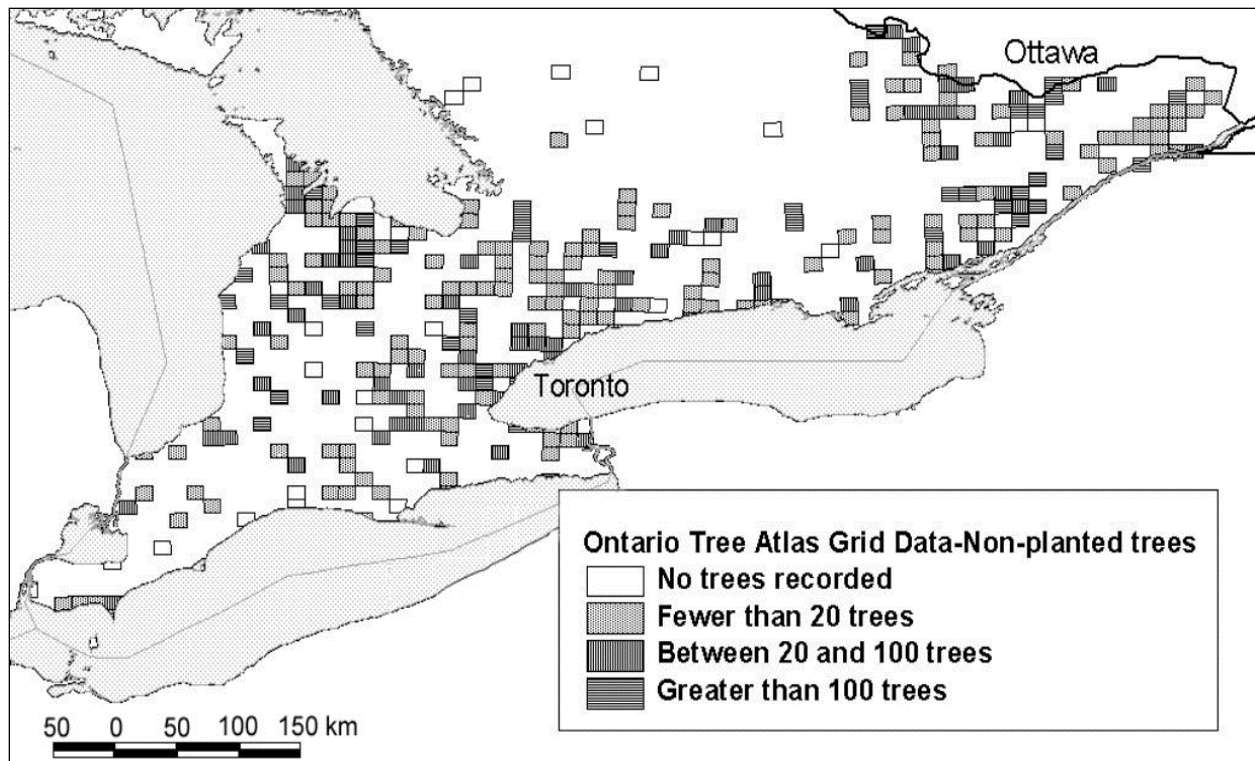


Figure 8. Ontario Tree Atlas data for non-planted Butternut. Tree Atlas volunteers recorded abundance by class for each tree species within an assigned 10 km x 10 km square during the period 1995 to 1999 (from COSEWIC 2003).

In Quebec (Figure 4), the species reaches its northern limit in the northern Rivière des Lièvres watershed (Antoine-Labelle County) and in the city of Québec region, both at roughly 47° latitude (FloraQuebeca 2009; CDPNQ 2015). Distribution of the species in Quebec is, however, strongly concentrated below latitude 45.8° along the Ottawa River, the St. Lawrence River and in the Eastern Townships as far east as the Sherbrooke Region (FloraQuebeca 2009; CDPNQ 2015).

Occurrences in New Brunswick (Atlantic National Ecological Area, COSEWIC 2014) are found primarily along a 300 km section of the Saint John River watershed from Grand Falls in Victoria County to Browns Flats in Kings County (Figure 9; AC CDC 2015). Smaller somewhat isolated subpopulations are also found in the upper Kennebecasis River watershed (Kings County), in the Petitcodiac River watershed (Westmorland County), and a 35 km section of the Southwest Miramichi River from Priceville to Upper Blackville in Northumberland County (AC CDC 2015). There is a single specimen from St. Stephen in southwestern-most New Brunswick along the Maine border (Consortium of Northeastern Herbaria 2016). No other records are known from nearby despite extensive recent searches of suitable habitat along the St. Croix River and elsewhere (AC CDC 2016). This record is assumed to represent either a planted individual or a misidentification of another species of walnut. Several unidentified naturalized saplings of a walnut species (not believed to be Butternut) were found along the St. Croix River during AC CDC fieldwork in 2011 (AC CDC 2016)



Butternut has been introduced as an exotic ornamental in Manitoba, Nova Scotia, and Prince Edward Island, with some establishment outside of cultivation. All reported occurrences in these jurisdictions are outside the species' natural range and are therefore excluded from status assessment as extra-limital introductions (COSEWIC 2010). Figure 6 shows the native range of Butternut in Canada, while figures 4, 7 and 9 show provincial distributions in Quebec, Ontario, and New Brunswick respectively.

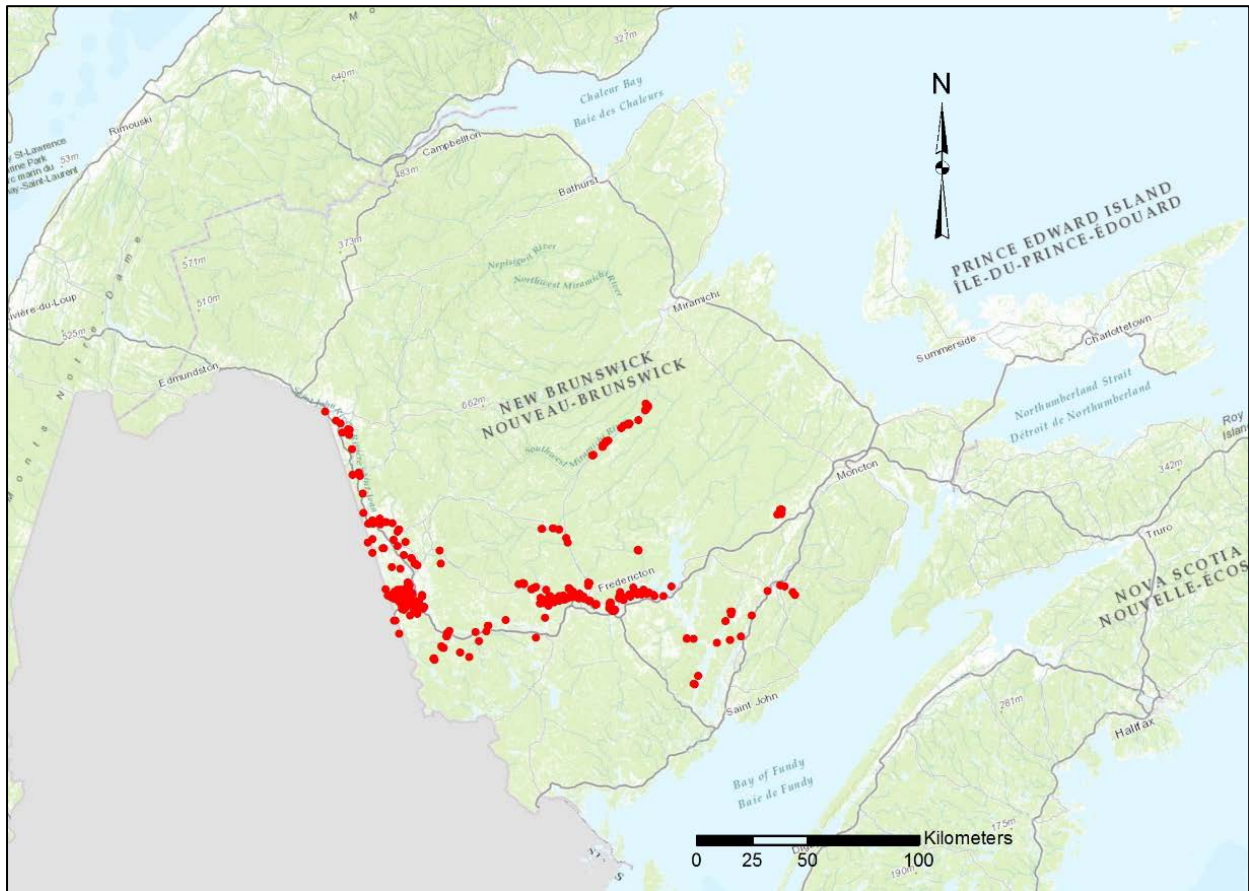


Figure 9. New Brunswick Butternut observation records compiled in the AC CDC (2016) database and documented through Canadian Forest Service fieldwork. Basemap from OpenStreetMap, containing data from GeoBase, GeoGratis (Department of Natural Resources Canada), CanVec (Department of Natural Resources Canada), and StatCan (Geography Division, Statistics Canada).

### Extent of Occurrence and Area of Occupancy

Based on data obtained from Ontario Natural Heritage Information Centre (ONHIC), Centre de données sur le patrimoine naturel du Québec (CDPNQ), Atlantic Canada Conservation Data Centre (AC CDC) and Canadian Forest Service (CFS), total extent of occurrence (EOO) is 399,440 km<sup>2</sup> if all observation records are considered and 266,920 km<sup>2</sup> if outlying occurrences (i.e., northern occurrences identified as potentially introduced

points in Figure 6) are excluded. The calculated EOO includes a considerable area of unsuitable aquatic habitat.

Index of area of occupancy (IAO) is difficult to quantify because occurrences are far from completely documented and the extent to which formerly occupied 2 km x 2 km grid squares have lost their subpopulations is unclear. The IAO prior to the arrival of Butternut Canker in the Ontario-Quebec area was likely a significant proportion of the 2 x 2 km squares intersected by its core range, which represents roughly 148,000 km<sup>2</sup>.

IAO based solely on occurrences available for this status report is 5,684 km<sup>2</sup>. This total significantly underestimates current IAO because of incomplete documentation of actual occurrence. The actual current IAO has likely declined fairly significantly from pre-canker levels, especially in regions with limited forest cover, where the number of Butternut trees in many 2 x 2 km grid squares would have been small even prior to Butternut Canker.

## HABITAT

### Habitat Requirements

Climatic conditions within Butternut's natural range vary significantly, with mean annual temperatures ranging from nearly 18°C in Warren County, Mississippi (NCEI 2015) to slightly over 4°C in Victoria County, New Brunswick (Environment Canada 2015). Frost-free periods within this region range from 105 days in the north to more than 210 in the south (Rink 1990). Butternut is the most winter hardy of the *Juglans* species (Ostry and Pijut 2000). Most of the Butternut's range has an annual precipitation of 800 to 1,200 mm, with averages up to 1,600 to 2,000 mm in the southern Appalachians and as low as 600 to 800 mm at the northwestern limit of its range in Minnesota (CEC 2010). The species occurs up to an elevation of 1,500 m in the Virginias (Clark 1965).

Butternut occurs predominantly in neutral to calcareous soils of pH 5.5 to 8, often in regions with underlying limestone, and is generally absent from acidic regions in Canada. It tends to reach greatest abundance in rich, neutral to calcareous, mesic loams and sandy loams (Schultz 2003; Lupien 2006) in floodplains, streambanks, terraces, hardwood coves and ravine slopes, but can occur in a wide range of other situations (Rink 1990; Ostry *et al.* 1994; Farrar 1995; Ostry and Pijut 2000; Brosi 2010; AC CDC 2015; CDPNQ 2015; ONHIC 2015). Butternut is seldom found on dry, compact and infertile soils (Rink 1990) but can occur on drier rocky soils, particularly those of limestone origin (Rink 1990; Farrar 1995; Ostry and Pijut 2000). In Ontario, there is a notable concentration of records where limestone is present at the soil surface along the Niagara Escarpment and in alvar regions just south of the southern margin of the Canadian Shield (OMNR 2011; ONHIC 2015). In a four year experiment in southern Quebec examining seedling performance in a variety of old field conditions, Butternut growth did not vary significantly by soil type. However, survival was significantly reduced in wetter soils (>30% soil water content) in which the surficial materials were marine sediments (Cogliastro *et al.* 1997). In Canada, however, it is frequently found in seepy, rich hardwood forest sites (Blaney and Mazerolle pers. obs).

1999-2015) that appear relatively moist. Rink (1990) and Brosi (2010) also note its affinity for moist loamy floodplain sites in the United States.

Butternut is a shade-intolerant tree (Rink 1990; St. Jacques *et al.* 1991; Doyon *et al.* 1998). In closed-canopy stands, it must be in the overstory to thrive (Ostry *et al.* 1994, 2003). Seedling establishment, growth and survival to maturity are largely restricted to stand openings, riparian zones and forest edges (Ostry *et al.* 1994; Hoban *et al.* 2012a). It has been called an early successional species (e.g., Rink 1990), and does occur in old field habitats (e.g., ONHIC 2015; AC CDC 2016); however, Brosi (2010) considered it predominantly a species of mature forest gaps and edges and Hoban (2010) found that although upland habitats facilitated more frequent colonization, upland populations were also more frequently extirpated compared to those in riparian forests.

In Canada, tree species most often found occurring in association with Butternut include (in alphabetical order) American Beech (*Fagus grandifolia*), American Elm (*Ulmus americana*), Basswood (*Tilia americana*), Bitternut Hickory (*Carya cordiformis*), Black Cherry (*Prunus serotina*), Bur Oak (*Quercus macrocarpa*), Eastern Hemlock (*Tsuga canadensis*), Hackberry (*Celtis occidentalis*), Northern Red Oak (*Quercus rubra*), Red Maple (*Acer rubrum*), Sugar Maple (*Acer saccharum*), White Ash (*Fraxinus americana*), White Oak (*Quercus alba*) and Yellow Birch (*Betula alleghaniensis*) (Rink 1990; Doyon *et al.* 1998; Ostry and Pijut 2000; Schultz 2003). In Ontario and extreme southwestern Quebec, Butternut also co-occurs with a suite of other deciduous trees of southeastern North America, including several Carolinian Forest species which have very limited Canadian ranges.

## Habitat Trends

Total habitat available for Butternut in Canada has declined significantly from pre-European settlement conditions. Forest cover within the Ontario and Quebec range of Butternut, representing >75% of the total Canadian range, is less than 30% compared to about 80% forest cover prior to settlement (National Forest Inventory 2013; but note caveats about unforested and edge habitat use below). The portion of this loss that has occurred since 1881 (within the past three generations) would probably be less than half given that most farming settlement within Butternut's Canadian range had occurred by 1871 (Dominion Bureau of Statistics 1951). In assessing Butternut habitat loss to forest clearance it is important to note that closed canopy mature forest is less suitable for Butternut than more sunlit forest edges, regenerating stands and hedgerows (see **Habitat**). Thus lower intensity farming may have neutral or locally beneficial effects on Butternut numbers even if amount of habitat is reduced. As farming intensifies, these potentially positive effects may be reduced. Since 1881, the best regions for annual crop cultivation, such as southwestern-most Ontario west of London, have seen non-plantation forest cover continue to decline through agricultural conversion (Larson *et al.* 1999; decline from 6.7% forest cover in 1967 to 4.5% in 2014 for Kent County, Bacher 2014), with intensive cultivation and few remaining hedgerows leaving little Butternut habitat. Urbanization has also permanently removed large areas of Butternut habitat, with a high proportion of that having occurred within the last 135 years. Overall, forest cover in southern Ontario and

Quebec increased since the 1920s and 1930s with abandonment of marginal agricultural land (Larson *et al.* 1999; Ministère des Ressources Naturelles 2013). Abandoned agricultural land is only accessible for Butternut if seed sources are nearby because of its slow rate of terrestrial dispersal (<100 m per generation; see **Dispersal and Migration**) but does represent a significant portion of occupied habitat in central and eastern Ontario, especially in rocky areas with limestone close to the surface (Boysen pers. comm. 2016; Brunton pers. comm. 2016).

The majority of the Canadian range of Butternut lies in the most densely populated and heavily industrialized region of Canada (Statistics Canada 2009) between the city of Québec and Windsor. Habitat loss from a wide variety of development continues, especially from urban sprawl and rural housing development (see **Threats – Habitat Conversion**). These losses are no longer necessarily compensated for by farmland abandonment elsewhere. For example, Li and Beauchesne (2003) documented a net forest loss of 412 km<sup>2</sup> in four administrative regions (Chaudière-Appalaches, centre-du-Québec, Montérégie and Lanaudière) from 1990 to 1998 and a net loss of 320 km<sup>2</sup> from 1999 to 2002 (a 30% higher rate than in the preceding period). Ongoing small habitat losses could become significant over one or more generations into the future.

The habitat trend for Butternut in New Brunswick is likely a small decline. The ecodistricts forming the majority of Butternut's range in New Brunswick remain strongly forested (> 60%) in comparison to Ontario and Quebec. However, most occurrences are found in the more agricultural and deforested portions of western Carleton and Victoria counties where conversion of forest to cropland (especially for potato cultivation) is still an issue (Blaney and Mazerolle pers. obs. 1999-2015). There is a longer-term provincial trend in New Brunswick of declining agricultural land associated with abandonment of marginal farms (COSEWIC 2003). However, the total area of land on farms in New Brunswick increased 1.8% between 2001 and 2006 (Statistics Canada 2006), then decreased 4.0% between 2006 and 2011 (Statistics Canada 2011). Effects on Butternut are unclear, but its occurrence is concentrated in the highly productive farmlands in the western part of the province that are least likely to be abandoned. Rural residential development is also locally affecting Butternut habitat on the Saint John River, especially near Fredericton where riverfront properties (frequently in areas of high Butternut abundance) are highly valued (Beardmore pers. comm. 2016).

Given Butternut's affinity for river shores and floodplains, the damming of watercourses has clearly caused localized habitat loss in all three provinces. The large number of dams and run-of-the-river generating stations along the Saint Lawrence River (Iroquois, Long Sault, Moses Saunders, Les Cèdres, Beauharnois, Rivière-des-Prairies), Ottawa River (Lac-des-Chats, Hull, Carillon) and many of their tributaries have cumulatively flooded a considerable area of highly suitable habitat for the species in which denser stands likely occurred historically (Butternut is or was a dominant species on some remaining Ottawa River islands, Brunton pers. comm. 2016). In New Brunswick, Butternut occurrences, especially stands in which it is a dominant species, are mainly concentrated along the Saint John River and its tributaries (Blaney and Mazerolle pers. obs. 1999-2015; AC CDC 2015). Two large dams on the Saint John River have flooded extensive ideal

Butternut habitat within the region of its densest occurrence in New Brunswick: Beechwood Dam (constructed 1955, flooding 34 km upstream to the Aroostook River) and Mactaquac Dam (constructed 1968, flooding 82 km to Woodstock).

Butternut Canker may be effectively reducing Butternut habitat because trees become more susceptible to canker with increased canopy closure (Brosi 2010), though recruitment may now be so reduced (Parks *et al.* 2013) and expected future mortality may be so high that this is not demographically significant over the longer term.

## BIOLOGY

### Life Cycle and Reproduction

Butternut is a relatively short-lived deciduous tree, rarely living more than 80-100 years (Rink 1990; Ostry *et al.* 1994; Ostry and Pijut 2000; Forest Gene Conservation Association 2012). It flowers from April to June. The species is monoecious (separate male and female flowers on the same tree), and wind-pollinated. In spring, male flower catkins emerge from small cone-like axillary buds on the previous year's branches and female flowers emerge on two- to eight-flowered spikes in the axils of new leaves on the current year's shoots (Dirr 1990). Male and female flowers on a given tree usually mature at different times, encouraging out-crossing (Rink 1990; Young and Young 1992; Ostry and Pijut 2000). Butternut is considered to be almost exclusively out-crossing (Young and Young 1992; Ross-Davis *et al.* 2008b). Butternut can hybridize with Japanese Walnut, English Walnut (*Juglans regia*), Manchurian Walnut (*Juglans mandshurica*) and Little Walnut (*Juglans microcarpa*) (Rink 1990; Michler *et al.* 2005; Ross-Davis *et al.* 2008b; Woeste and Pijut 2009). Hybridization with Japanese Walnut is now known to be fairly common across the native range of Butternut (Hoban *et al.* 2009; McLaughlin and Hayden 2012; Beardmore pers. comm. 2015; Rioux pers. comm. 2015). See **Morphological Description** (above), **Threats** (below) and Table 1 for more information on hybridization.

The fruit matures in September and October in the year of pollination. Fruits occur singly or in clusters of two to seven and usually remain on the tree until mid- to late October, after leaf fall (Talalay *et al.* 1984; Rink 1990; Zurbrigg pers. comm. 2017). Although the embryo can remain dormant for two years (OMNR 2000) it usually germinates in the spring following seed fall (Rink 1990). Dormancy can be broken by cold stratification at 1 to 5°C for 90 to 120 days (Brinkman 1974; Young and Young 1992). Seeds reportedly do not survive more than two years in the soil (Woeste *et al.* 2009).

Seed bearing starts around age 20 and peaks at age 30 to 60 (Ostry *et al.* 1994; Ostry and Pijut 2000). For this report, generation time (the average age of reproductive individuals) is thus roughly estimated at the median point within this range, 45 years. Good seed crops occur irregularly (maximum frequency every two to three years) with light crops during intervening years. Low viable seed yields may be caused by insect damage, spring frost or lack of pollination (Rink 1990).

Younger trees and saplings are capable of re-sprouting from stumps (Rink 1990).

## Physiology and Adaptability

Butternut tolerates a wide range of climatic conditions, as evidenced by its large latitudinal range. Soil pH appears to be a physiologically limiting factor in Canada, where the species occurs mostly on soils of pH 5.5 to 8 (Schultz 2003; Lupien 2006) and is largely or entirely absent from acidic regions. Butternut is the most cold-tolerant of the North American walnuts and occurs in USDA hardiness zones 3 to 7 (Ostry and Pijut 2000). Its northern and southern range limits are several hundred kilometres north of those of Black Walnut. Although it is frequently found in river floodplains and forested seeps, it is not a wetland species. In a Quebec study of seedling performance in calcareous old field soils of various textures and moisture levels, growth was not significantly affected by soil type but survival was significantly reduced in imperfectly drained sites having soil moisture content of 49% (Cogliastro *et al.* 1997). In a study comparing the physiological tolerances of Butternut, Japanese Walnut, Buartnut (*Juglans × bixbyi*) and Black Walnut, Crystal and Jacobs (2014) found that Butternut was negatively affected by flooding but exhibited a relatively high tolerance to drought.

Butternut is an early-successional tree (Rink 1990; St. Jacques *et al.* 1991; Doyon *et al.* 1998). It is fast-growing, particularly as a seedling, and can grow despite considerable lateral competition (Rink 1990; Ostry *et al.* 1994). The species does not tolerate shade and maturing individuals must reach the overstory to thrive (Ostry *et al.* 1994). If source populations remain nearby, the species can benefit from various natural and anthropogenic disturbances that create openings in the forest canopy, including insect pest outbreaks, blow-down and timber harvesting. Fires can also create openings for seedling establishment, although Clark (1965) states that Butternut does not sprout following top-killing fires, and fire disturbance is currently rare in the Canadian range of Butternut.

The nut is considered intolerant of long-term storage and remains viable for three to five years if stored in sealed containers at temperatures just above freezing (USDA 1948). Satisfactory storage can be obtained for at least two years if stored in closed containers at 80% to 90% relative humidity and +5 to 0°C. The nuts cannot tolerate drying to low water contents (e.g., 5% water content) and are sensitive to temperatures below -40°C (Wang *et al.* 1993).

Butternut is commonly and easily propagated by seed and through grafting onto Black Walnut rootstock, which is more readily available (Ostry and Pijut 2000). Vegetative propagation via rooted cuttings is ineffective except possibly on saplings under 12 years old (Pijut and Moore 2002; Pijut 2004; Zurbrigg pers. comm. 2017). Micropropagation through the induction of somatic embryogenesis (Pijut 1993, 1997) and cryopreservation of embryonic axes (Beardmore 1998; Beardmore and Vong 1998) have both been shown to be potentially viable tools for the propagation and long-term preservation of Butternut germplasm.

## Dispersal and Migration

No published studies have investigated pollen dispersal potential in Butternut, but the documented dispersal potential of other wind-pollinated temperate tree species suggests that a considerable portion of Butternut pollen may be disseminated over distances exceeding 1 km (Sork and Smouse 2006; Craft and Ashley 2007; and Robichaud 2007, for Black Walnut). Pollen dispersal could therefore potentially allow for genetic exchange to take place between subpopulations separated by several kilometres. However, a parentage analysis carried out by Hoban *et al.* (2012a) showed that the majority of parent to parent distances were less than 100 m and found no signs of cross-pollination occurring over distances greater than 500 m. This suggests that cross-pollination potential over longer distances may be low and that cross-pollination over distances on the order of hundreds of kilometres is unlikely. Subpopulations in New Brunswick are therefore likely to be genetically isolated from those in Quebec and New England.

Due to their considerable weight, nuts typically fall directly beneath the parent tree, where they may be carried further down-slope by gravity. Where Butternut occurs in riparian and floodplain habitats, water flow could represent an important vector for dispersal, as the nut falls while still encased in a buoyant husk (Laricchia *et al.* 2015). During spring freshet and other high-water events, nuts could be carried downstream over considerable distances.

Seed-caching rodents, particularly squirrels, are known to seek out Butternuts and play an important role in dispersal (Ostry *et al.* 2003; Moore 2005; Moore *et al.* 2007; Woeste *et al.* 2009; Hoban *et al.* 2012a). Squirrel caches are typically not more than 40–60 m from the seed source (Ivan and Swihart 2000; Hewitt and Kellman 2002a,b in southern Ontario; Goheen and Swihart 2003; Moore *et al.* 2007), though they have been documented dispersing other species of walnut up to 168 m (Stepanian and Smith 1986; Tamura *et al.* 1999; Tamura and Hiyashi 2008). In Canada, the predominant disperser would be Grey Squirrel, *Sciurus carolinensis*, abundant through most of Butternut's Canadian range but uncommon or absent in parts of the New Brunswick range where it is a relatively recent arrival (Woods 1980). Red Squirrel (*Tamiasciurus hudsonicus*) also co-occurs across Butternut's Canadian range and caches the seeds of both native walnuts (Laricchia *et al.* 2015; Hanrahan 2016) but is uncommon or absent in purely deciduous stands in southernmost Ontario (iNaturalist 2016; Blaney pers. obs. 1989-2015). Eastern Chipmunk (*Tamias striatus*), which occurs commonly throughout the Canadian range of Butternut, may also be important in dispersal, although some references suggest Butternuts are too large to be consumed by the species (Rosell 2001). Fox Squirrel (*Sciurus niger*) is an important disperser in the United States (Laricchia *et al.* 2015), but within Butternut's Canadian range is restricted to Pelee Island in southernmost Ontario (Schneider and Pautler 2009).

Butternuts are probably too large and hard-shelled for most birds, but American Crow (*Corvus brachyrhynchus*) could be a significant disperser. Cristol (2005) found that American Crows dispersed English Walnuts in northern California. About 77% of the nuts transported away from parent trees were cached in surrounding fields, most within 1-2 km

of the source but 5% at a distance > 2 km. Crows cached an estimated 2,000 nuts/km<sup>2</sup>/year in fields 1-2 km away.

Hoban *et al.* (2012a) found that genetically inferred parent-offspring distances in a regenerating Butternut population indicated limited seed dispersal. All maternal parent-offspring distances were less than 100 m, with most being less than 40 m. Due to its limited seed-dispersal capacity, Butternut rarely colonizes openings not adjacent to seed sources and distances as little as 50 m may represent isolating barriers (Hewitt and Kellman 2002). Stochastic long-distance water-borne seed dispersal events could allow for rescue to take place between subpopulations joined by water flow, but would not allow for rescue to occur in non-riparian environments or across watersheds.

An investigation of chloroplast haplotypes by Laricchia *et al.* (2015) found results consistent with the eastern portion of Butternut's range having been colonized from a single southern refugium, potentially in the vicinity of southern Georgia or Florida. They noted, however, that northward migration rates produced by squirrel dispersal were insufficient to cover the 2,300 km northeastward to New Brunswick in 18–20,000 years. They suggested that Pleistocene megafauna such as mammoths and ground sloths may have been significant in the early recolonization northward to New England, and that First Peoples may have played a significant role in dispersal thereafter, consistent with evidence in Wykoff (1991). Humans also presently act as important long-distance dispersal vectors through movement and cultivation of the species, both within and beyond its natural range.

## Interspecific Interactions

As in other *Juglans* species, Butternut exudes the naphthoquinone compound juglone through its root system (Rink 1990; Schultz 2003). This substance is toxic to many other tree species, ornamentals and crop plants and also inhibits the growth of Butternut seedlings (Rietveld 1983; Schultz 2003; see also an extensive listing of species reported as affected or unaffected by *Juglans nigra* in Willis 2000). Allelopathy may play an important role in reducing interspecific competition for soil nutrients and sunlight, though there remains significant uncertainty regarding the significance of *Juglans* allelopathy in natural communities (Willis 2000).

Butternut can represent an important food source for wildlife, especially in areas without other high-quality mast sources (Ostry *et al.* 1994). The highly nutritious nuts are eaten by many animals including mice, squirrels, chipmunks and deer and the developing nuts are consumed by Common Grackles (*Quiscalus quiscula*), (Rink 1990; Ostry *et al.* 2003; Waldron 2003) and likely other birds. Seed caching rodents such as squirrels and chipmunks also act as seed dispersal agents (Ostry *et al.* 2003; Woeste *et al.* 2009; Hoban *et al.* 2012a).

White-tailed Deer (*Odocoileus virginianus*) may impact Butternut regeneration by browsing leaves and twigs and through antler-rubbing (Ostry *et al.* 2003; Woeste *et al.* 2009; Boysen pers. comm. 2015) and Butternut is reported as a favoured deer browse (Van Dersal 1938, as cited in Woeste *et al.* 2009).



Butternut trees support a diverse insect fauna including many specialists of walnut species that occur on few or no other genera (Ostry and Pijut 2000). A few of these (most notably the weevil *Eubulus parochus*, family Curculionidae, and the Butternut Agrilus beetle, *Agrilus juglandis*, family Buprestidae), may be entirely dependent on Butternut (Halik and Bergdahl 2006; Anderson 2008; Paiero *et al.* 2012; Webster pers. comm. 2016). Both these species are known from Ontario, Quebec and New Brunswick. In Wisconsin and Vermont, Katovich and Ostry (1998) identified 87 insect species on Butternut in the orders Coleoptera (beetles), Thysanoptera (thrips), Hemiptera (in the broad sense, true bugs), Diptera (flies), Lepidoptera (moths) and Hymenoptera (sawflies, wasps, ants and bees). Handfield (2011) listed 31 butterfly and moth species that use Butternut in Quebec as a host plant. A few Butternut specialist insects highlighted in the forest or agricultural pathology literature and considered native to Canada are described below.

Butternut Curculio (*Conotrachelus juglandis*) is a weevil (family Curculionidae) occurring throughout the Canadian range of Butternut (Bousquet *et al.* 2013) and is likely important in spreading Butternut Canker (Halik and Bergdahl 2006). Adults and larvae create feeding and oviposition wounds on new shoots and young fruit in the tree crown (Rink 1990; Ostry and Pijut 2000; Halik and Bergdahl 2002) and can cause severe damage to nuts, young stems, petioles and branches (Johnson and Lyon 1988). The Walnut Shoot-borer moth (*Acrobasis demotella*, family Pyralidae) has been considered an important pest species for commercial growers, capable of causing serious damage to both Butternut and Black Walnut in Ontario (Syme and Nystrom 1988). A single larva of this species can kill a shoot or leader and result in a crooked tree (Martinat and Wallner 1980). Walnut Caterpillar (*Datana integerrima*, family Notodontidae), a common species in southern Ontario, southern Quebec and the northeastern U.S. (USDA 1985; Troubridge and Lafontaine 2007), is considered an important defoliator of *Juglans* species (Farris and Appleby 1979). Butternut Woolly Sawfly (*Eriocampa juglandis*, family Tenthredinidae), although not considered a serious pest, can sometimes become locally abundant (Schultz 2003). In Canada, this species is known to occur throughout the native range of Butternut (Smith 1979). Striped Caterpillar (*Datana angusi*, family Notodontidae) and the micro-moth *Gretchena amatana* (family Tortricidae) have also been noted as pest species of minor importance in Ontario (Nystrom and Britnell 1994). *Gretchena concitaticana*, known from Black Walnut (Miller 1987) and documented in Ontario (North American Moth Photographers Group 2015), may also occur on Butternut. Larvae of the fruit fly *Rhagoletis suavis* (family Tephritidae) feed in developing walnut and Butternut husks and can cause significant damage to nuts (Beck 1932). Several other *Rhagoletis* species are known from commercial walnuts (Boyce 1934) and likely also occur on Butternut. The Walnut Aphid (*Chromaphis juglandicola*, family Aphididae), a European species known from Ontario, is an external phloem feeder on leaflets that can cause leaflet curling (Favret and Eades 2015). Leafhoppers (family Cicadellidae) of unknown species are reported to transmit a virus that causes a condition called Hopper Burn (Zurbrigg pers. comm. 2017).

In addition to Butternut Canker there are a number of fungal and bacterial diseases known to affect Butternut. Only those considered to cause significant damage are included here.

Walnut Bunch Disease, believed to be caused by a mycoplasma-like bacterium (Rink 1990), instigates normally dormant axillary and adventitious buds to develop prematurely, causing a “witch’s-broom” of sucker-like shoots and undersized chlorotic leaves on large limbs and trunks (Seliskar 1976; Meador *et al.* 1986). This abnormal growth lacks cold-hardiness and suffers winter-kill, and affected branches do not produce normal nut crops (Berry 1973).

Aside from *Ophiognomonia clavignenti-juglandacearum* (Oc-j), the causal agent of Butternut Canker, the most notable fungal pathogen of Butternut is *Melanconis juglandis*, which often secondarily infects dead or dying portions of trees affected by Oc-j (Nicholls *et al.* 1978; Loo *et al.* 2007; see discussion of Butternut Canker under **Threats**). Other fungal cankers noted as significant in young Butternut plantations in Quebec are caused by the genera *Fusarium* and *Phomopsis* (COSEWIC 2003). *Armillaria gallica*, a species of honey mushroom, has been reported as causing root disease on Butternut (McLaughlin 2001). This species favours hardwood hosts and infects and kills stressed trees. Among foliage diseases the most damaging is an anthracnose leaf spot caused by *Marssonina juglandis*, the anamorph or imperfect stage of the ascomycete *Gnomonia leptostyla*. This pathogen reportedly infects and kills young shoots as well as foliage (Black *et al.* 1977; Myren 1991; CFS 1994), in some cases blighting most of the leaf and causing it to fall prematurely (Hepting 1971, as cited in Schultz 2003).

Although they are relatively minor threats, these pathogens and several other minor diseases can accelerate the decline of trees already suffering from Butternut Canker.

## POPULATION SIZES AND TRENDS

### Sampling Effort and Methods

No fieldwork was carried out specifically for the preparation of this status report. Because Butternut is not a commercially significant lumber species and tends to be a minor component of forest communities, provincial government forest inventories provide limited data. In all, 863 occurrences (1 km separation distance) were compiled for this status report, and the Ontario Tree Atlas (Figure 8; OMNR 2011, not yet digitized) and FGCA have hundreds of additional records, but many more sites remain undocumented. There have been no efforts to systematically assess the abundance of Butternut in Canada.

### Abundance

The previous status report (COSEWIC 2003) estimated the Ontario population to be approximately 13,000, stating that this was a very conservative estimate. One of the report’s writers has since noted that the estimate represented only the number of trees on eastern Ontario properties reported to the Forest Gene Conservation Association (a very small fraction of the actual number of occurrences) rather than the total Ontario population (Boysen pers. comm. 2015). ONHIC (2015) has databased 7,000+ Ontario observation

records representing 408 element occurrences<sup>2</sup> (Figure 7). Ongoing discovery of new sites clearly shows knowledge of fine-scale distribution to be far from complete (Oldham pers. comm. 2016). The high rate of tree mortality in Ontario populations (40% per decade based on Wilson pers. comm. 2016) makes it very difficult to extrapolate records of mixed age into a current population total.

Population size has never been estimated in Quebec. The CDPNQ does not actively track Butternut occurrences, meaning that efforts to compile all potentially available records have been limited. Its database includes 233 occurrence records for Butternut (Figure 4). Forest plot inventories carried out by the Ministère des Ressources Naturelles du Québec have detected the species in 378 plots in southern Quebec, 39 of which had Butternut as a dominant or co-dominant species (>25% canopy cover or basal area). The extent of duplication between CDPNQ data and forest inventory plots is unknown in the province.

The current population of mature trees in Ontario and Quebec may still be in the tens of thousands to 100,000+ (Brunton pers. comm. 2016; based primarily on high abundance observed in the Ottawa region, which exceeds that found by the Forest Gene Conservation Association (FGCA) in other regions in Ontario; Boysen pers. comm. 2016), but much more systematic work would be required to produce a more precise population estimate.

No recent New Brunswick abundance estimates are available but provincial population size was estimated in the previous status report (COSEWIC 2003), for which experienced New Brunswick Department of Natural Resources (NB DNR) field staff identified roughly 370 discrete stands in 50 sites and estimated numbers of mature trees by site in exponential categories: 1-10 (11 sites), 11-100 (23 sites), 101-1,000 (10 sites), and 1,000+ (6 sites). This totalled between 7,000 and 18,000 mature trees (rounded to nearest thousand, and assuming the six sites of 1,000+ had exactly 1,000 trees). This process would have missed large numbers of trees in isolated private woodlots in Carleton and Victoria counties and smaller numbers elsewhere, in addition to underestimating any sites actually over 1,000 trees. Whatever the 2003 New Brunswick population, it is clearly now reduced. In the Saint John River valley, where most New Brunswick Butternut occurs, dead trees are almost as common as living ones (Blaney and Mazerolle pers. obs. 1999-2015), almost all living trees are visibly unhealthy, and recruitment is likely significantly depressed as in the remainder of the range (Hoban *et al.* 2012a; Boraks and Broders 2014; Wilson pers. comm. 2016). Extensive field observation suggests that the current population of mature trees in New Brunswick may still be in the high thousands to 10,000+ (Blaney and Mazerolle pers. obs. 1999-2015; Beardmore pers. comm. 2016), but much more systematic work would be required to produce a precise population estimate.

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<sup>2</sup> In theory, element occurrences are sites supporting a subpopulation that could contribute to the survival or persistence of the species, though in practice for this species they simply represent sites with at least one living Butternut at the time of observation, separated from other occurrences by at least 1 km (Oldham pers. comm. 2016). Ontario element occurrences include 346 ranked as Verified Extant (observed in past 20 years, but not necessarily actually still extant because of canker mortality), 61 ranked as Historical (where the species has not been observed in over 20 years) and one considered Extirpated. Roughly 44% of observation records, however, lack any indications of abundance, tree age or tree health.

## Fluctuations and Trends

In the absence of disease, Butternut matures around 20 years of age in good growing conditions and has a life expectancy of 70-100 years (Ostry 1998; Forest Gene Conservation Association 2012). As a long-lived organism with a generation time estimated at 45 years, it would not exhibit significant fluctuations in total population size across the Canadian range.

Butternut Canker has caused dramatic declines in the global Butternut population and is the foremost threat to the survival of the species (see **Threats**). The disease has been in the United States somewhat longer than in Canada and its progression there can inform what can be expected in Canada in the coming 20 years. Rates of Butternut Canker infection are near 100% in the United States (Schultz 2003 as cited in LaBonte *et al.* 2015). Total mortality in the United States is not well quantified but USDA Forest Service (1995) estimated 77% of Butternut trees in the southeast were dead by 1995, and mortality in the United States since that time has been substantial (e.g., 60% mortality from 2001 to 2012 in a Wisconsin site initially hoped to have genetically resistant individuals, LaBonte *et al.* 2015). Michigan is believed to have lost 90+% of individuals and Wisconsin had lost 80+% of individuals by 2004 (Ostry, in Freedman 2016; Cummings-Carlson and Guthmiller 1993; Cummings-Carlson *et al.* 2004).

In Ontario and Quebec, the species has also suffered dramatic losses. Cumulative mortality is probably now well above 50%. Mortality in 1992 was already 27% in the OMNRF Cambridge District (southwestern Ontario), and although mortality was not found at that time in eastern Ontario, infection rates there were already 90% (CFS Forest Insect and Disease Survey unit data, as cited in COSEWIC 2003). Very roughly estimating ongoing mortality since 1992 based on the 5.43% annualized rate from 2008 to 2014-15 measured by Wilson pers. comm. (2016; see **Threats – Butternut Canker**) would translate to a 93.2% reduction from pre-canker levels in Cambridge District and a 77% reduction in eastern Ontario. The rate of infection in surviving trees in Ontario now appears near 100%, and mortality continues to proceed rapidly. Wilson pers. comm. (2016) found 99.7% infection in 1,221 trees examined in 60 plots across southern Ontario, and recorded 38% mortality between 2008 and 2014-2015. Seedling establishment and survival to maturity is also reduced (only three plots out of 60 with any seedlings or saplings in 2014-2015 and almost no recruitment into reproductive age classes from 2008 to 2014-2015; Wilson pers. comm. 2016, but see discussion in **Threats – Butternut Canker**). Canadian recruitment is otherwise not well documented, but low recruitment rates would be expected in Canada based on an extensive demographic study that showed recruitment essentially ended in Great Smoky Mountains National Park (Kentucky and Tennessee) in 1980 at or near the time of Butternut Canker's arrival (Parks *et al.* 2013). Quebec data paints a similar overall demographic picture to Ontario, with 80 to 95% of trees infected and extensive mortality observed, though not generally well quantified (Blais 2011; Tanguay 2011; Nadeau-Thibodeau 2015b; Rioux pers. comm. 2015).

Disease progression is less advanced in New Brunswick (70% infection in 403 trees examined in 2013 to 2015, Beardmore pers. comm. 2016) but total canker mortality may

already be in the range of 20-50% and is increasing significantly, with dead or nearly dead trees common and the majority of mature trees exhibiting significant crown die-back presumed to be associated with canker infection (Blaney and Mazerolle pers. obs. 1999-2015; see **Threats**).

Diseased trees are often killed in the span of a few years, but larger trees (which are not girdled as rapidly by cankers) can sometimes live as long as 30 years (Ostry *et al.* 1994). Cankers can be aged by growth rings, and ages of 20+ years are known (CFS data cited in COSEWIC 2003). Disease tolerance and survival has been associated with more open habitats (Parks *et al.* 2013) and with drier, upland habitats on thin soils (LaBonte *et al.* 2015), though Wilson (pers. comm. 2016) did not observe this association in a study of 1,221 trees in 60 plots in southern Ontario. Putatively disease-tolerant trees are only 1-5% of the current population (Boysen pers. comm. 2015; Rioux pers. comm. 2015), some of which may represent hybrids with non-native species that are questionably countable as Butternut by COSEWIC standards (Michler *et al.* 2005; Hoban *et al.* 2009, 2012a; McCleary *et al.* 2009; COSEWIC 2010; Zhao and Woeste 2010; Wilson pers. comm. 2016). Efforts to find resistant trees have yet to produce strongly resistant cultivars. For example, although Ostry and Moore (2008) found some genetic basis for canker resistance, LaBonte *et al.* (2015) found that there was little genetic basis for resistance in a formerly large Wisconsin subpopulation in which resistance has been investigated since 2001. Barring identification and propagation of resistant genotypes, rates of infection and mortality documented in Canada (especially via Ontario monitoring plot data, Wilson pers. comm. 2016), suggest that current numbers will follow the trajectory observed in the United States and decline further by significantly more than 50% within one generation (45 years), and that Butternut could be at or near to extinction within three generations (135 years). The extensive population declines that have already occurred make projected losses relative to pre-canker populations significantly higher than the estimates above.

Population losses from Butternut Canker are on top of population reductions resulting from habitat conversion in the past three generations (135 years). As noted in **Habitat Trends**, forest cover will not perfectly correlate with Butternut population because some landscape clearance could increase populations, and because much of current forest cover is regenerated from formerly cleared areas that differ in tree species composition compared to primary forest (Flinn and Marks 2007), and may lack poorly dispersed tree species like Butternut (which has a terrestrial dispersal rate estimated at under 100 m per generation, see **Dispersal and Migration**). However, total population reductions in Ontario and Quebec prior to Butternut Canker as compared to pre-settlement levels (going back further than 135 years) can be roughly estimated by loss of forest cover. Forest cover has been reduced from more than 80% to about 37% within Butternut range (Butt *et al.* 2005, see **Threats**). The portion of this loss that has occurred since 1881 (within the past three generations) would probably be less than half given that most farming settlement within Butternut's Canadian range had occurred by 1871 (Dominion Bureau of Statistics 1951). The many hydroelectric dams on river and stream systems have likely been a fairly significant additional factor causing population reductions in the past 135 years because they tend to affect the riparian sites with the densest Butternut populations (see **Habitat Trends**). Pre-canker losses to forest clearance are substantial in New Brunswick as well,

but are likely somewhat less than in Ontario and Quebec because of less intensive agriculture and settlement.

## **Rescue Effect**

Water-borne dispersal might allow for movement of seeds between the United States and Canada across the lower Great Lakes and the Saint Lawrence River in Ontario. Current-borne seeds would be especially likely to enter Canada across the Quebec border along major rivers and streams in the Lake Champlain – Richelieu River and Saint-François River watersheds. River transport of seeds could also occur very locally via watercourses flowing into western New Brunswick from Maine (Meduxnekeag River, Presque Isle Stream and several smaller brooks), though the population in eastern Maine is believed to be much smaller than that in New Brunswick (Cameron pers. comm. 2015). In non-riparian habitats, the seeds of Butternut are mainly dispersed by small seed-caching rodents, which typically do not carry them over distances greater than 100 m (see **Dispersal and Migration**). Animal-mediated international dispersal would be possible in Quebec and New Brunswick, but of limited occurrence in Ontario because the international border is almost entirely water within Butternut range. The value of seed dispersal in rescuing the Canadian population would be limited because there is no evidence of greater canker resistance in adjacent United States populations.

Documented pollen dispersal potential of other temperate wind-pollinated tree species suggests that Butternut pollen may commonly travel over distances greater than 1 km (Sork and Smouse 2006; Craft and Ashley 2007). This would allow for genetic exchange (i.e., a genetic rescue effect) to occur between populations in the U.S. and those in southern Ontario and southern Quebec, but this would be of significance primarily if it were to confer greater resistance to Butternut Canker and there is no evidence of increased resistance in the adjacent United States population.

Deliberate human dispersal from the United States is also possible as there is a community of tree nut enthusiasts, in addition to general horticulturalists, who could transport seeds across the border (Wilson pers. comm. 2017).

## **THREATS AND LIMITING FACTORS**

### **Threats**

Direct threats to Butternut assessed in this report are organized and evaluated based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2009). Threats are defined as the proximate activities or processes that directly and negatively affect the Butternut population. Results on the impact, scope, severity, and timing of threats are presented in tabular form in Appendix 1. The overall calculated and assigned threat impact is Very High for Butternut.

Narrative descriptions of the threats are provided below in the general order of highest to lowest overall impact threats.

#### Invasive Non-native Pathogen: Butternut Canker Fungus (IUCN Threat 8.1)

The foremost threat to Butternut is Butternut Canker, a lethal fungal disease caused by *Ophiognomonia clavigignenti-juglandacearum* (Broders and Boland 2011). A thorough review of Butternut Canker across the North American range of Butternut is given below, but the most valuable data for purposes of assessment are presented first.

In 2008, Richard Wilson, Forest Program Pathologist, Ontario Ministry of Natural Resources and Forestry (pers. comm. 2016) developed 60 monitoring sites on public lands in a wide variety of habitats (mature upland forest, old field forest, riparian forest, open parkland) across the southern Ontario range of Butternut, in accordance with the Canadian Butternut Monitoring Strategy protocol. Each plot included a variably sized but fairly extensive area, generally with a minimum of 25 Butternut trees. Plots were resampled in 2008 and 2014-2015 and over those six to seven years, there was 38% mortality of mature trees. Of the 1,221 monitored trees in the plots in 2008, by 2014-2015 only one large tree and four small trees of 3 cm to 11 cm diameter retained vigour scores of 1 (meaning no visible evidence of disease; Millers *et al.* 1991). The single large tree was subsequently genetically confirmed as a Butternut x Japanese Walnut hybrid. Richard Wilson reports a greater frequency of trees having better vigour scores in the Ottawa River Valley, but major declines in vigour in that region and throughout Ontario between 2008 and 2014-2015. Contrary to observations elsewhere suggesting open-grown trees were more resistant to canker, there was little pattern in mortality by habitat, with mortality frequent in both highly competitive forest habitat and fully open parkland. Wilson's study sites also showed very little regeneration, with saplings and seedlings observed in only 14 sites in 2008 and three plots in 2014-2015 and no evidence of significant recruitment into reproductive size classes. Assuming that recruitment to maturity is minimal or no longer occurring (see **Fluctuations and Trends**), and the rate of decline documented by Wilson (38% over 7 years, or 5.43% annually) continued, there would be 91% decline from the initial population within one generation (45 years) and 100% decline by year 84, well short of three generations (135 years). Documented rates of infection in Quebec are between 80+% (Blais 2011) and 95% (of 163 individuals in the Eastern Townships, Tanguay 2011), and are slightly lower in New Brunswick (70% of 403 trees in 2013 to 2015, Beardmore pers. comm. 2016), presumably because of the disease's later arrival there. There is no evidence to suggest that rates of decline and ultimate loss in Quebec and New Brunswick are likely to be less than those documented in Ontario and elsewhere in Butternut's range outlined below.

Based primarily on field observations that have yielded records of 14,000 trees on 500 sites in eastern Ontario (Renfrew, Lanark, Leeds and Grenville counties to the Quebec border), the FGCA (Boysen pers. comm. 2016; Fleguel pers. comm. 2017) notes the following, which may temper some conclusions or extrapolations above:

- Throughout southern Ontario some individual trees remain vigorous though diseased, despite steady decline of other trees in the same population. This may be the result of genetic tolerance to the canker, micro-site effects, minimal stresses (Butternut Curculio, drought, shading) or a combination of these factors. Signs of canker tolerance include: trees callusing over cankers or other wounds; trees with healthy canopy but a cankered bole; or single healthy trees surrounded by heavily cankered trees.
- Butternut regeneration in eastern Ontario is relatively uncommon, but in some situations, considerable regeneration (e.g., 252 seedlings and saplings less than 9 cm DBH on a 5 ha site) has been observed. Recruitment into reproductive sizes on these sites has not been evaluated.
- Landowner education, conservation and intervention to provide the conditions for regeneration could result in persistence of an Ontario Butternut population beyond 84 years, the time of extirpation roughly extrapolated above from observed mortality rates.

Significant disease-caused damage in Butternut was first reported in New York in the early 1920s (Graves 1919, 1923) and initially attributed to the fungus *Melanconis juglandis* (Graves 1923). It is now believed that these early reports of die-back and mortality in Butternut may have been the first documented cases of what came to be called Butternut Canker (Broders *et al.* 2012, 2015). The first reports recognizing Butternut Canker came from Wisconsin in 1967 (Renlund 1971), although the cause was not fully understood until extensive research by Nair *et al.* (1979), who successfully isolated the fungus in pure culture and described it as a new taxon, *Sirococcus clavignenti-juglandacearum*. Later phylogenetic study determined that the fungus is a member of the genus *Ophiognomonia* and not *Sirococcus*, and it was subsequently reclassified as *Ophiognomonia clavignenti-juglandacearum* (henceforth referred to as *Oc-j*) (Broders and Boland 2011).

Although the origin of *Oc-j* is not clear and the fungus is not known from outside North America, its sudden appearance, high level of virulence and rapid spread suggest that it was most likely introduced (Furnier *et al.* 1999; Woeste *et al.* 2009). The sexual stage of the fungus is unknown (Nair *et al.* 1979). Low genetic variability observed throughout the range of the fungus in North America led to suggestions that its presence stemmed from a single introduction event (Furnier *et al.* 1999), but more extensive investigation by Broders *et al.* (2012) found three genetically distinct groups, indicating that there were likely at least three independent introduction or emergence events. Broders *et al.* (2012) suggest that *Oc-j* is either an exotic fungus introduced on horticultural plant species such as the closely related Japanese Walnut or on foreign wood products, or that *Oc-j* is a minor native pathogen of a different North American species that has made a host jump.

The Butternut Canker affects trees of all ages, killing both the seedlings and mature trees, regardless of soil type (Nair *et al.* 1979; Ostry and Pijut 2000; Ostry and Woeste 2004). Hyphal pegs created by the fungus rupture the outer bark of infected trees, exposing asexual fruiting bodies which release masses of conidia (asexual spores) throughout the growing season during times of high relative humidity or rainfall (Tisserat and Kuntz 1983). Extruded spore masses are initially bound in mucus and eventually liberated by flowing



water or rain drop impact (Nicholls 1979; Tisserat and Kuntz 1982; Cree 1995). Young cankers caused by the disease are typically inky-black, whitish-margined, and elongated-oval in shape (Nicholls *et al.* 1978). These typically originate at leaf scars, buds, lenticels, and naturally occurring or insect-caused openings in the bark (Nicholls *et al.* 1978). Branch cankers usually appear first in the upper or lower crown (Nicholls *et al.* 1978; Tisserat and Kuntz 1984; Ostry and Pijut 2000). Large numbers of conidia are subsequently carried downward by water flow during rainfall events, allowing spores to lodge in bark openings along the tree trunk and on exposed roots (Tisserat and Kuntz 1983). The fungus initially affects the outer bark, rapidly causing the disintegration of bark cells and invading underlying wood where it eventually kills the vascular cambium (Kuntz *et al.* 1979; Ostry *et al.* 1994; Schultz 2003). Older branch, stem and root cankers are perennial, often covered by shredded bark and bordered by several callus layers (Kuntz *et al.* 1979; Ostry *et al.* 1994).

Although saplings are often quickly killed, mature trees may survive many years before succumbing to the disease due to severe crown die-back and gradual girdling from coalescing stem cankers (Kuntz *et al.* 1979; Ostry 1997a; Schultz 2003). Any sprouts developed from heavily infected trees are also infected and die within a few years (Ostry *et al.* 1994).

Spores of *Oc-j* are disseminated by wind, rain splash and as aerosols during rainfalls, remaining viable in air for at least 8 hours during weather conditions of cool temperatures and overcast skies (Tisserat and Kuntz 1983). In an airborne state, spores could be swept up above the tree canopy by air movement and dispersed over distances of 40 km or more (Tisserat and Kuntz 1983).

Although it is believed that insects act as vectors in long-distance dispersal of the pathogen, the extent of this role is not entirely understood (Halik and Bergdahl 2002; Stewart *et al.* 2004; Broders *et al.* 2015). Sampling in Vermont and Wisconsin identified 87 different insect species on Butternut, 57 of which were collected with some frequency and six of which (all beetles) were collected under the bark of diseased trees and carried the fungus (Katovich and Ostry 1998). In Vermont, Halik and Bergdahl (2002) found at least 17 species of beetles in eight families that carried *Oc-j* conidia. They also found that six to eleven percent of Butternut Curculio individuals carried the fungus. This may be especially significant because the Butternut Curculio creates feeding and oviposition wounds on Butternut shoots (Halik and Bergdahl 2002). Handfield (2011) lists 31 butterfly and moth species in Quebec that use Butternut as a host plant, all of which could also act as vectors. Insects may transport conidia via feeding, ovipositing, overwintering underneath the bark of dead or dying branches, or by movement between fallen infected branches and branches in the canopy (Halik and Bergdahl 2002; Stewart *et al.* 2004; Broders *et al.* 2015). Birds could also act as long-distance vectors between isolated subpopulations (Nicholls 1979), as could humans through harvesting and movement of lumber and firewood (Ostry and Woeste 2004).

The fungus occurs inside seeds, and seedlings emerging from infected seeds quickly develop cankers and die (Orchard 1984). The ability of the pathogen to persist for extended periods of time in infected nut-meats may partially explain very limited Butternut regeneration in some areas (Nair 1999) and could be a factor in long-distance dispersal of *Oc-j* (Schultz 2003).

*Oc-j* can survive saprophytically on dead trees and successfully sporulate for at least 20 months (Tisserat and Kuntz 1984). Dead and dying trees, particular heavily-cankered ones, may therefore act as major sources of conidia and significantly contribute to spreading the disease within a population.

Alternative host species may play an important role in the persistence and spread of the disease (Broders *et al.* 2015). Although Butternut seems to be the only species significantly affected by the pathogen, other species in the genus *Juglans* are susceptible to infection, including Black Walnut, English Walnut, Japanese Walnut, Heartnut (*J. ailantifolia* var. *cordiformis*) and hybrids between Heartnut and Butternut (*J. x bixbyi*) (Innes 1997; Orchard *et al.* 1982; Ostry 1997b; Ostry and Moore 2007; Broders and Boland 2011). Inoculations of greenhouse-grown saplings showed the fungus was able to colonize other hardwoods, most of which co-occur with Butternut in Canada (\*): Pecan (*Carya illinoensis*), Shagbark Hickory\* (*Carya ovata*), Bitternut Hickory\*, American Hazel\* (*Corylus americana*), Beaked Hazel\* (*Corylus cornuta*), American Chestnut\* (*Castanea dentata*), Black Cherry\*, Northern Red Oak\*, Bur Oak\*, Black Oak\* (*Q. velutina*) and White Oak\* (Ostry 1998b; Ostry and Moore 2007). These results indicate that various other forest species may serve as reservoirs of the pathogen and raise the possibility that *Oc-j* originated as a pathogen of a genus other than *Juglans* (Michler *et al.* 2005). Throughout its range, Butternut is often found in stands containing one or several of the potential other hosts identified above.

No fully canker-resistant Butternuts have ever been confirmed. There is some evidence suggesting genetic tolerance may be present at very low frequency in natural populations (Ostry *et al.* 2003; Ostry and Woeste 2004; Michler *et al.* 2005; Ostry and Moore 2008; Forest Gene Conservation Association 2012; Woeste *et al.* 2009; Nadeau-Thibodeau 2015a). Work to identify tolerant or resistant Butternut for use in research and population recovery has been carried out in the United States and Canada (above authors, Beardmore pers. comm. 2015; Rioux pers. comm. 2015). Phenotypically tolerant or resistant trees growing in close proximity to heavily-cankered individuals have been known to remain disease-free for 10-20 years (Ostry and Woeste 2004; McKenna *et al.* 2011), but this putative resistance is rare and apparently overcome by artificial inoculation, suggesting that stem inoculations bypass an important resistance mechanism (McKenna *et al.* 2011). Nearly all individuals initially identified as potentially resistant eventually begin exhibiting signs of the disease after prolonged exposure to the pathogen (Rioux pers. comm. 2015). Moreover, genetic screening using DNA-based markers shows that individuals identified in situ as being potentially resistant commonly have some degree of hybridity with Japanese Walnut (Michler *et al.* 2005; Hoban *et al.* 2009; McCleary *et al.* 2009; Woeste *et al.* 2009; Zhao and Woeste 2010; McKenna *et al.* 2011). Hybrids do not necessarily have long-term tolerance, as Butternut Canker mortality has also been observed in confirmed wild hybrids in Ontario (Wilson pers. comm. 2016).

Following the initial 1967 report of the disease (Renlund 1971), *Oc-j* was documented and/or spread throughout the entire range of Butternut in North America (Ostry 1997a; Ostry and Woeste 2004). The rate of spread of this epidemic over the entire range of the host was faster than other lethal diseases of eastern North American hardwood forest species (Broders *et al.* 2015). *Oc-j* has devastated Butternut throughout its range, causing widespread declines of over 80%, widespread local extinctions, and threatening the survival of Butternut as a viable naturally occurring species (Fleguel 1996; Ostry 1998; Ostry *et al.* 2003; Schultz 2003; Bergdahl and Bergdahl 2011). Mortality will likely rise significantly, as nearly all remaining trees are affected by the disease (Bergdahl and Bergdahl 2011). Regeneration is also significantly hampered in infected populations, as seed production is greatly reduced in heavily infected trees and the seedlings that these trees produce often quickly succumb to the disease (Ostry and Pijut 2000; Ostry and Woeste 2004). For example, seedlings were observed in only three of 60 plots (with sites selected in 2008 based on having roughly 25 trees) from throughout Butternut range in Ontario during 2014-2015 (Wilson pers. comm. 2016) and large-scale demographic studies in the United States show very little recruitment into reproductive age classes has occurred since Butternut Canker became widespread (Parks *et al.* 2013; Boraks and Broders 2014). FGCA reports seedlings as being somewhat more frequent than suggested by Wilson (Boysen pers. comm. 2016), but the extent to which these are maturing into reproductive individuals is unclear.

Additional details on the pathogenesis of Butternut Canker and diagnosis of the disease can be found in Kuntz *et al.* (1979), Nair *et al.* (1979), Tisserat and Kuntz (1983), Tisserat and Kuntz (1984), Ostry *et al.* (1994), Woeste *et al.* (2009), Broders and Boland (2010, 2011) and Broders *et al.* (2015).

In Ontario, Butternut Canker was first identified in 1991 by the Forest Insect and Disease Survey (FIDS) unit of CFS, but 1992 FIDS surveys found cankers in the Cambridge area that were 20+ years old indicating that it had been present since 1972 or slightly earlier (Davis *et al.* 1992; data cited in COSEWIC 2003). In 1992, the FIDS unit found the canker at 22 of 30 sites sampled in southwestern Ontario. At that time, whole-tree mortality was most evident in the Ontario Ministry of Natural Resources' Cambridge District, where 27% of the trees surveyed had already been killed by the disease. Although there was no whole-tree mortality recorded in the eastern half of the province in 1992, greater than 90% of the trees examined in that region were found to be infected. Given the annualized mortality rates of Ontario Butternuts documented by Wilson (pers. comm. 2016), many or perhaps the majority of the Ontario trees found in 1992 are likely now dead (5.43% compounded annually from 1992 to 2016 would give 77% decline, though actual rates of decline are unclear over that period). At present, the disease is found throughout the entire native range of Butternut in Ontario. Butternut monitoring plots across southern Ontario found a 99.7% infection rate in 1,221 trees in 2014-2015 (Wilson pers. comm. 2016). However, Butternut Health Assessments (part of an Ontario provincial Species at Risk permitting process), indicate that a certain percentage of trees either do not have Butternut Canker or are showing some level of resistance to the disease. Between Aug 2013 and Jan 2017, within 127 registrations, qualified Butternut Health Assessors identified 384 category 2 trees (i.e. trees that do not have Butternut Canker or the disease is not advanced).

In Quebec, *Oc-j* was first detected in 1990, where it was observed in natural forest near Fort-Coulonge and at Waltham in the Ottawa River Valley (Innes and Rainville 1996). In 1994, the disease was detected in natural forest along the lower Ottawa Valley at Fassett, near Montréal at Deux-Montagnes and in the Eastern Townships at Frelighsburg, Glen-Sutton, Ascot Corner and Sainte-Cécile de Milton (Innes and Rainville 1996; Nadeau-Thibodeau 2015a). The following year, Innes and Rainville (1996) also report the presence of *Oc-j* on diseased Butternut and Black Walnut at nurseries far removed from any known occurrences, at Duchesnay (northwest of the city of Québec) and Berthierville (Lanaudière Region). In an effort to conserve healthy specimens and genetic diversity for use in recovery efforts, the Ministère des Forêts, de la Faune et des Parcs worked with the CFS in 1996 to establish four Butternut plantations inside and outside of the natural range of the species (Nadeau-Thibodeau 2015a). Within a few years, the pathogen was detected within these plantations and the project was abandoned (Bouchard *et al.* 2010). In 2001, screening from the Ministère de la Faune, des Forêts et des Parcs found that *Oc-j* had infected thousands of Black Walnut trees in a nursery at Berthier (Ministère des Ressources Naturelles 2002). During a two-year survey and monitoring effort carried out in 2008 and 2009, canker mortality was found at all 17 sampling sites, located throughout the natural range of Butternut in Quebec (Innes and Nadeau-Thibodeau 2009; Bouchard *et al.* 2010; Nadeau-Thibodeau 2015a).

Detailed surveys recently carried out at nine sites in the Centre du Québec Region found that canker was prevalent at all sites and that average percentage of diseased trees across all sites exceeded 80% (Blais 2011). Similarly, inventories in the Lac Saint-François and Cap Tourmente National Wildlife Areas, near Cornwall and the city of Québec respectively, have shown that over 80% of trees are affected (Nadeau-Thibodeau 2015b) and Tanguay (2011) found 95% infection of 163 individuals in the Eastern Townships. At present, *Oc-j* is known to occur throughout the provincial range of Butternut and, although healthy trees still occur in very small numbers, completely unaffected stands are no longer found (Rioux pers. comm. 2015). Some regeneration (but not necessarily recruitment into reproductive age classes) is still occurring in Quebec's Eastern Townships. Tanguay (2011) found seedlings in 13% of floodplain sites (n=15), 33% of highly calcium-rich mesic upland sites (n=24) and in 7% of moderately calcium-rich mesic upland sites (n=27), but she found saplings only in 7% of the floodplain sites and nowhere else. Rioux (pers. comm. 2015) reports that saplings in Quebec do not live long (with canker as the presumed cause of mortality), even in sites artificially opened to promote regeneration.

Butternut Canker was first detected in New Brunswick in 1997, when the disease was found at five sites in Carleton County, along the Saint John River at Peel, Stickney, Upper Brighton and Riverbank, and on the Meduxnekeag River at Jackson Falls (Harrison *et al.* 1998, 2005; Hopkin *et al.* 2001). Further survey efforts in 2004 by the CFS and the New Brunswick Department of Natural Resources resulted in the discovery of *Oc-j* at an additional four Carleton County and two Victoria County sites (Harrison *et al.* 2005). Sampling by CFS from 2013 to 2015 confirmed Butternut Canker throughout the provincial range of Butternut, with 70% (285 of 403) of trees being cankered, and the presence of *Oc-j* was detected at several sites on the lower Southwest Miramichi River in central New Brunswick (Beardmore pers. comm. 2015). The stands found along this river are isolated

from other occurrences by roughly 45 km and were previously considered the last remaining unaffected native Butternut subpopulations in Canada and possibly range-wide. Where Butternut reaches its greatest frequency in Carleton and Victoria counties, the proportion of badly diseased trees appears to be over 50% and dead trees are common, sometimes roughly as common as live ones (Blaney and Mazerolle pers. obs. 1999-2015). Observed rates of mortality now probably underestimate cumulative canker effects because many of the first trees killed have lost their bark and fallen, and are becoming hard to spot and identify to species (Blaney and Mazerolle pers. obs. 1999-2015).

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

Most of Butternut's Canadian range is in the densely populated Great Lakes Plains National Ecological Area of southern Ontario and Quebec in which human landscape alteration is extensive and new development is frequent. As a result, remaining Butternut occur frequently adjacent to existing development or in the footprint of new developments or agricultural expansion. Collectively, development threats are very small relative to the extreme threat posed by Butternut Canker, and they are not expected to impact more than 10% of the Canadian population of Butternut in the next ten years (see Threat Calculator in Appendix 1). The threat to Butternut posed by development is also mitigated in Ontario and New Brunswick (see **Legal Protection and Status**; Sabine pers. comm. 2016), but not in Quebec (Pohu pers. comm. 2016), where no provincial protection is in place, by provincial policies that come into play when the species is identified via an Environmental Impact Assessment as present within a development footprint (see **Habitat Protection and Ownership**).

In Ontario, Butternut removal for development requires a permit under the Ontario *Endangered Species Act* and compensatory actions intended to provide a net benefit to the species (see **Legal Protection and Status**). The Ontario Environmental Registry (2016) lists 83 development projects since 2000 for which permits have been issued to remove or transplant Butternut or for which Butternut management plans have been enacted (allowing development with no Butternut removal). Projects include housing and commercial developments, quarries and aggregate pits, golf courses, solar power projects, and road construction and maintenance. Removal of up to 10 Category 2 (poor health but still alive) trees is allowed without a permit, but with compensatory planting, and such cases would not be tracked in the above system. Smaller developments, most significantly single residences being built in rural areas and conversion of uncropped areas to cropland, generally do not go through environmental assessments and thus would not be tracked in the Ontario Environmental Registry (2016). Thus additional loss of Butternut through habitat conversion is likely occurring at a low level on an ongoing basis. Based on similar provincial rates of economic growth (Conference Board of Canada 2016), development pressure in the densely populated St. Lawrence River corridor in Quebec would likely be similar to that in Ontario. Development pressure within Butternut range in New Brunswick is somewhat lower than in Ontario and Quebec because of lower population density, but all the above threats do occur (Blaney and Mazerolle pers. obs. 1999-2015), most notably along the

Saint John River in the vicinity of Fredericton, where Butternut occurrence is frequent and where rural residential estates with a river view are in demand (Beardmore pers. comm. 2016). Residential development within the floodplain is generally restricted by zoning and the *New Brunswick Clean Water Act*, but cutting trees for views that often accompanies residential development is not. As noted under **Legal Protection and Status**, New Brunswick occurrences are somewhat protected under provincial policy in projects requiring Environmental Impact Assessment or Crown Land development review, though most small-scale development would not trigger either of these processes.

#### Wood Harvesting (IUCN Threat 5.5)

The threat described here includes only forest harvesting on sites that are subsequently left to regenerate and does not include removal via forest conversion to other uses. Forestry would not be a major threat to persistence in Canada in the absence of Butternut Canker because at many logged sites later regeneration might result in numbers remaining stable, or even increasing over time because of canopy opening. However, seedlings and saplings are increasingly rare in the Ontario and Quebec population (see **Threats – Butternut Canker**), and there are likely few trees entering mature age classes even in New Brunswick where seedlings and saplings remain fairly common (Mazerolle and Blaney pers. obs. 1999-2015; AC CDC 2016). Additionally, if any genetic tolerance or resistance is present, loss of remaining healthy trees through logging will eliminate that genetic potential.

Butternut is generally protected from harvesting (see **Legal Protection and Status**), but targeted harvesting of Butternut was listed as a significant threat in the Recovery Strategy for the Butternut in Canada (Environment Canada 2010), which noted that landowners in the United States and Ontario were pre-emptively removing Butternut before the trees died and lost their value. As canker mortality increases and healthy Butternut becomes rarer on the landscape, this motivation for Butternut removal may be decreasing. Additionally, in Ontario, all Butternut are protected until assessed by MNR-designated Butternut Health Assessors. Those that are assessed and reported to MNR as unhealthy can then be cut, harmed, or sold. Those assessed as healthier can only be removed or harmed if a replacement planting is done, or if a permit under the *Endangered Species Act* is issued with the requirement that planting or archiving activities are done representing a net benefit to the species (OMNRF 2015; planting of Butternut is done in excess of those removed). No equivalent policy relevant to tree cutting is in place in Quebec or New Brunswick outside of federal land. Deliberate, unauthorized cutting of Butternut in Ontario may sometimes occur in order for a development-oriented landowner to avoid dealing with Species at Risk regulations (Brunton pers. comm. 2016). Inadvertent cutting undoubtedly occurs to some extent in Ontario by landowners or inexperienced or under-trained contractors who are unaware of the species. Cutting of Butternut is unregulated in Quebec and New Brunswick, and is likely especially frequent in western New Brunswick, where about 95% of known occurrences are on private land (AC CDC 2016), use of hardwood firewood for heat is especially frequent (Statistics Canada 2010), a large pulp mill at Nackawic in the central part of Butternut's provincial range uses hardwood almost exclusively (Aditya Birla AV Group 2016) and cutting of hardwood stands supporting Butternut is common (Mazerolle and Blaney pers. obs. 1999-2015).

### Introduced Genetic Material: Hybridization with Japanese Walnut (IUCN Threat 8.3)

In discussing hybridization with non-native walnuts as a threat it should be noted that because of the lack of disease resistance thus far found in genetically pure Butternut (Woeste *et al.* 2009; McKenna *et al.* 2011; Nadeau-Thibodeau 2015a), serious suggestion (e.g., Boraks and Broders 2014) has been made that propagation and dissemination of more resistant Japanese Walnut x Butternut hybrids may be the best available option for restoring the ecological role of Butternut into wild systems and preserving Butternut genes. Similar to the backcross breeding program which has been used to breed blight resistance into American Chestnut from Chinese Chestnut (*Castanea mollissima*) (Hebard 2005), hybrids and subsequent backcrosses could offer a means of developing resistant Butternut cultivars (Michler *et al.* 2005; Broders *et al.* 2015). Current practice in Canada (including COSEWIC assessments – COSEWIC [2010], Appendix E7), however, treats all confirmed hybrids as non-Butternuts with no specific protection.

Butternut cannot hybridize with native Black Walnut, but is known to hybridize with at least three walnut species of Asian and European origin, all of which are cultivated in Canada. Hybrids with English Walnut, resulting in *J. x quadrangulata*, can occur but are uncommon and not highly fertile (Woeste *et al.* 2009). Butternut also occasionally crosses with Manchurian Walnut (Rink 1990). The most prevalent hybrid, *J. x bixbyi*, results from the crossing of native Butternut with Japanese Walnut, a species first introduced in the U.S. in the mid-1800s and widely cultivated in North America over the last century (Woeste *et al.* 2009). Because most cultivated Japanese Walnut are the variety called Heartnut, hybrid offspring have commonly been referred to as Buarts or Buartnuts. Believed to be self-fertile (Zhao and Woeste 2010), Buartnut is able to cross with other hybrids and backcross with parent taxa, producing confusing combinations of traits (Ross-Davis and Woeste 2007; Zhao and Woeste 2010). Hybrid trees are highly vigorous, high yielding (Orchard *et al.* 1982) and have greater resistance to Butternut Canker (Nair 1999; Michler *et al.* 2005; Ostry and Moore 2007; Boraks and Broders 2014). For these reasons, hybrids of unknown provenance are believed to have been commonly selectively propagated as Butternuts over the last century (Woeste *et al.* 2009). Buartnuts can be very difficult to distinguish from pure Butternut based on morphology alone and are often impossible to identify with any certainty unless twigs and seeds can be examined (Michler *et al.* 2005; Ross-Davis *et al.* 2008b; Woeste *et al.* 2009). Though no single morphological trait is sufficient to distinguish between pure and hybrid Butternuts, Table 1 (modified from Woeste *et al.* 2009) summarizes morphological traits which, in combination, can allow for the identification of hybrids. Catling and Small (2001) provide a detailed key to all native and introduced walnut species and hybrids in Canada.

The degree to which introgression of Japanese Walnut genes is common within the natural range of Butternut has only recently been investigated, following the development of DNA-based markers which allow for effective screening (Ross-Davis *et al.* 2008b, McCleary *et al.* 2009; Zhao and Woeste 2010; Parks *et al.* 2014). Naturally occurring hybrids are now known to be common across the natural range, with highest incidences found in fragmented semi-rural landscapes (Michler *et al.* 2005; Hoban *et al.* 2009, 2012b,). Woeste

*et al.* (2009) note that in some areas (not specified) in the U.S., virtually all “Butternut” are actually hybrids with some level of Japanese Walnut introgression. Zhao and Woeste (2010) found that most hybrids examined were not in fact true *J. x bixbyi*, but second generation hybrids (F<sub>2</sub>), backcrosses or other complex hybrids. The common occurrence of Japanese Walnut and hybrids raises questions as to the purity of trees identified as being canker-resistant (Michler *et al.* 2005; Hoban *et al.* 2009, 2012b; McCleary *et al.* 2009; Zhao and Woeste 2010).

Hybridization with exotic *Juglans* species is considered a potential threat for Butternut in Canada (Environment Canada 2010). In areas where Japanese Walnut and/or Butternut come into close proximity to natural Butternut, extensive hybridization and recurrent backcrossing could threaten the genetic integrity of affected populations. In Canada, hybridity has been detected throughout the range of Butternut. Hybrids are noted as common in Ontario (McLaughlin and Hayden 2012), with 10% of the healthiest single individuals selected from 60 Butternut monitoring sites by Wilson (pers. comm. 2016). In Eastern Ontario, however, hybrids are reported uncommon away from urban centres (Zurbrigg pers. comm. 2017). Hybrids are present but uncommon overall in both Quebec (Rioux pers. comm. 2015) and New Brunswick (Beardmore pers. comm. 2015). In Quebec, some candidate trees tested for potential resistance have turned out to be hybrids (Rioux pers. comm. 2015).

#### Problematic Native Species: White-tailed Deer (IUCN Threat 8.2)

White-tailed Deer are known to favour young Butternut trees for browsing and antler rubbing (Van Dersal 1938; Woeste *et al.* 2009; Boysen pers. comm. 2015), though this is not currently believed to be a significant threat (see Threats Calculator – Appendix 1). The observations of Ostry *et al.* (2003, excerpted below) in Wisconsin suggest that, under some circumstances, deer browse and antler rubbing could have a non-negligible impact on Butternut regeneration.

“Deer have impacted the Butternut regeneration in two ways, by browsing and antler rubbing. While the frequency of browsed seedlings can be high, the majority of them are not seriously damaged. Deer browse may however be a net asset by controlling the competing trees and brush. Deer tend to use salient saplings to rub the velvet off their antlers as they harden. This behavior also has some role in mating and territorial dominance. Butternut tends to occupy open areas in stands where deer activity is high and this may account for the high incidence of damage observed, however, based on observations deer may preferentially select Butternut seedlings for unknown reasons. This damage may be as significant as that caused by browsing.”

Deer significantly affect the composition of forest plant communities in the eastern United States and southeastern Canada (Russell *et al.* 2001). In northern hardwood forest, increases in deer density were found to cause declines in favoured browse species, producing altered plant communities dominated by species avoided by deer or resilient in response to deer browsing (Horsley *et al.* 2003). In the mixed conifer–hardwood forests in the Great Lakes region, widespread habitat modification and extirpation of native predators



have acted to boost populations of White-tailed Deer to historically high densities (Rooney and Waller 2003). Projected climate change scenarios throughout the Canadian range of Butternut suggest that winter temperatures will become milder (Lemmen *et al.* 2008), which could lead to increases in White-tailed Deer populations and browsing pressure. Impacts from deer browsing and damage on young Butternut has been observed in Ontario (Boysen pers. comm. 2015), suggesting that in some situations, protection from deer may be necessary in order to foster regeneration.

### Climate Change (IUCN Threat 11)

Current and future climate change effects on Butternut are difficult to adequately assess. Projected climate change scenarios for this century suggest milder winters, warmer mean summer temperatures and higher precipitation for much of Butternut's Canadian range (Lemmen *et al.* 2008). Southern Ontario, southern Quebec and New Brunswick are predicted to see an increase in mean temperature of 2 to 4°C by 2050, with maximum warming occurring in winter (Lemmen *et al.* 2008). These temperatures will be more similar to areas currently in the centre of Butternut's natural range so might improve growth and reproduction (if it were not suppressed by canker), unless changes in temperature and moisture regime favoured increased development of Butternut Canker.

Climate change can influence forest pathogen effects through: 1) direct effects on the development, survival and dispersal of pathogens, 2) changes in tree physiology that can influence resistance to pathogens and herbivore vectors and 3) indirect effects on the abundance of insect vectors of tree pathogens (reviewed in Ayres and Lombardero 2000). Milder winters, warmer growing seasons and changes in moisture availability can increase the prevalence and severity of tree pathogens by reducing winter mortality of insect vectors and increasing the development rate of insects and pathogens during the growing season (Weed *et al.* 2013). Scope and severity of diseases may be affected by climatic influences on sporulation and infection and/or changing tree susceptibility to infection (Sturrock *et al.* 2011; Weed *et al.* 2013). Warmer and longer growing seasons could promote the development of Butternut Canker in Canada because of the importance of humidity and rainfall in the production and dispersal of conidia (Tisserat and Kuntz 1983).

## **Limiting Factors**

### Low Genetic Diversity

In a study investigating genetic diversity in northeastern subpopulations of Butternut (nine subpopulations sampled in Quebec, New Brunswick and Vermont), Morin *et al.* (2000) concluded that parameters of genetic diversity (polymorphic loci, number of alleles per locus and average heterozygosity) in these subpopulations had very low values, much below those estimated for Black Walnut or other boreal tree species. Range-wide studies of genetic diversity (Hoban *et al.* 2010; Larrichia *et al.* 2015) in Butternut demonstrate a higher diversity in centrally-located United States populations and a marked reduction in diversity in Canadian subpopulations at the edge of the species' range in Ontario, Quebec and New Brunswick (although New Brunswick supports some unique genetic variation (Hoban *et al.*

2010; Romero-Severson 2012; Hoban pers. comm. 2015; Beardmore pers. comm. 2016)). If low genetic diversity corresponds to a low adaptive potential, Canadian subpopulations may be less capable of coping with environmental changes (Morin *et al.* 2000; Reed and Frankham 2003; Hoban *et al.* 2010) and less likely to develop resistance to the Butternut Canker (Schultz 2003).

Genetic diversity is likely to be further reduced by the widespread mortality caused by Butternut Canker to the point that small subpopulations may suffer a loss of fitness via inbreeding depression (Reed and Frankham 2003; Geburek and Konrad 2008). In a naturally regenerating stand of Butternut, Hoban *et al.* (2012a) detected a shift in allele frequencies and a loss of diversity due to a small number of contributing parents.

### High Levels of Seed Predation

There is no evidence to suggest that excessive seed predation by native species is a threat to Butternut, but this was listed as a possible threat in the recovery strategy (Environment Canada 2010), where it was speculated that seed predator populations (Common Grackle, Grey Squirrel and White-tailed Deer) augmented by human land use changes could threaten seedling establishment already limited by canker. Insect granivory and vertebrate predation of nuts on the tree can lead to significantly lower viable seed yields (Ostry *et al.* 1994). The highly nutritious seeds of Butternut are consumed by small mammals, deer, birds, humans and various insects. Squirrels and other small seed-caching rodents actively seek out Butternut seeds (Ostry *et al.* 1994; Woeste *et al.* 2009), acting as important dispersal agents (Waldron 2003; Environment Canada 2010; see also references in **Dispersal and Migration**). Common Grackles, which often occur in higher densities in urban and agricultural landscapes (Graber and Graber 1963; Emlen 1974), are also reported to feed on immature fruit (Rink 1990).

### **Number of Locations**

For the purposes of COSEWIC assessment, locations are defined by the scale of the most immediate threat. The primary threat to the species is clearly the fungal disease Butternut Canker, which is now present throughout the entire Canadian range. Although the canker arrived at different times across the Canadian range and there is some variation in current rates of infection and cumulative mortality, all Canadian occurrences will likely be subject to 90+% loss within one to three generations. The entire Canadian population should therefore be considered a single location.

## **PROTECTION, STATUS AND RANKS**

### **Legal Protection and Status**

In Canada, Butternut was originally assessed as Endangered by COSEWIC in 2003. The species is currently listed as Endangered and included on *Schedule 1* of the federal *Species at Risk Act* (Government of Canada 2015).

In Ontario, it is currently granted provincial protection under *Schedule 3* of the *Endangered Species Act* (2007). In accordance with the act, the harming of the species or its habitat is generally prohibited, although the harvesting or removal of Butternut on private properties is allowed under certain circumstances. Trees are classified under three categories as follows: Category 1 – Non-retainable (heavily diseased trees), Category 2 – Retainable (healthy or slightly diseased trees) and Category 3 – Archivable (trees that show potential for disease tolerance). Following inspection and reporting (to MNRF) by a designated Butternut Health Assessor, any non-retainable trees can be cut, while a maximum of 10 retainable trees can be cut (OMNRF 2015), provided the proponent meets additional requirements such as the planting of Butternut seedlings that result in an “overall benefit” to the species. It is not yet known if the planting of small diameter trees that may rapidly succumb to Butternut Canker will truly replace the “retainable” larger trees.

In Quebec, Butternut is not protected through provincial legislation. It is, however, included in the *Liste des plantes vasculaires susceptibles d’être désignées menacées ou vulnérables* (MDDELCC 2015), an official list of sensitive plant species which is ratified by ministerial order. Species included on this list must be targeted by any surveys prompted by the provincial environmental impact assessment process. In some cases, measures to mitigate impacts on these species can be a requirement for project approval.

Butternut is listed under *New Brunswick’s Species at Risk Act* (2013), but with no prohibitions in place. During Environmental Impact Assessments and Crown land development reviews, New Brunswick Department of Energy and Resource Development (formerly Department of Natural Resources) requests proponents of potential development projects to survey for it in areas where it occurs, and may ask for mitigation measures when development projects might affect the species.

In the U.S., Butternut was formerly listed under Category 2 on the list of Endangered and Threatened Plants under the *Endangered Species Act*. This category was for species that showed evidence of vulnerability, but for which data were insufficient. The species was, however, delisted in 1995, owing to an amendment of the act in which Category 2 was entirely removed. It is, however, presently considered a Species of Special Concern, meaning that it requires species management considerations and could be considered for listing under the act, but that supporting information is insufficient at this time (Farlee *et al.* 2009). Natural heritage program websites list Butternut state-level status designations as follows: Kentucky (Threatened), Tennessee (Threatened), and Wisconsin (Special Concern).

## **Non-Legal Status and Ranks**

Butternut is globally ranked as apparently secure (G4; NatureServe 2015) and nationally ranked as vulnerable to apparently secure in the United States (N3N4; NatureServe 2015) but the global rank has not been reassessed since 2006 and was assigned based on the now disproven assumption that canker resistant trees were widespread (NatureServe 2015). Butternut is also considered Imperilled to Vulnerable

(N2N3) in Canada, Imperilled (S2) in Quebec and Ontario (S2?) and Critically Imperilled (S1) in New Brunswick (AC CDC 2015; CDPNQ 2015; ONHIC 2015). The species is actively tracked by the ONHIC and the AC CDC. In Quebec, Butternut has not been actively tracked by the CDPNQ since 2013, but it is listed on the provincial list of *Espèces susceptibles d'être désignées menacées ou vulnérables au Québec* which does not confer any special protection.

In the United States, Butternut is generally considered a sensitive and rare species (Schultz 2003). Subnational status ranks in the U.S., as listed by NatureServe (2015) unless otherwise noted, are: Alabama (S1), Arkansas (S3), Connecticut (SNR – not ranked), Delaware (S3), District of Columbia (S1), Georgia (S2), Illinois (S2), Indiana (S3), Iowa (SU - unrankable), Kentucky (S2S3), Maine (SU), Maryland (S2S3), Massachusetts (S4?), Michigan (S3), Minnesota (S3), Mississippi (S2), Missouri (S2), New Hampshire (S3), New Jersey (S3), New York (S4), North Carolina (S2S3), Ohio (S4), Pennsylvania (S4), Rhode Island (SU), South Carolina (S3), Tennessee (S3), Vermont (S3), Virginia (S3?), Washington (SNA - exotic), West Virginia (S3), Wisconsin (S2S3; Wisconsin Natural Heritage Inventory 2016). The jurisdictions in which the species is ranked S4 have likely not updated their ranks to reflect declines and ongoing threats associated with Butternut Canker.

In addition to S-ranks and state legal status, Butternut is on a Watch List for Indiana and Massachusetts, is under review for future listing in Pennsylvania and is Exploitably Vulnerable (listed under state law but without prohibitions) in New York. Restrictions on harvest of Butternut on some public lands in the United States have been enacted and silvicultural guidelines for the management of Butternut have been developed (Ostry *et al.* 1994; Schultz 2003). Some federal and state agencies have established management policies aimed at retaining Butternut on public lands (Woeste *et al.* 2009). In 1992, the Minnesota Department of Natural Resources placed a moratorium on the harvest of healthy Butternut on some state lands (Schultz 2003).

## **Habitat Protection and Ownership**

Available distribution and abundance data cannot determine the portion of the Canadian population on protected land, but it is clearly not large. The Mixedwood Plains Ecozone (Environment Canada 2013; essentially identical to the Great Lakes Plains National Ecological Area of COSEWIC 2014), representing most of the Ontario and Quebec range of Butternut, includes only 1.8% protected area (Environment Canada 2013) and relatively little Crown land. In New Brunswick, protected areas only cover 1.7% of the species' range, and roughly 87% of the New Brunswick range consists of privately owned land. Prior to Butternut Canker, Butternut was probably present in many smaller protected or managed lands in which it has now been extirpated. Nonetheless, the widespread distribution of Butternut means that it still occurs in a large number of provincial parks and provincial nature reserves, Conservation Areas (public lands in Ontario administered by government-affiliated non-profit agencies called conservation authorities), non-governmental nature reserves, municipal parks, provincial Crown land and other lands with some degree of conservation management. For example, all 60 plots of the OMNRF

monitoring study (Wilson pers. comm. 2016) occur on public lands. Butternut is protected on federal land and it occurs on numerous Indian Reserves and other federal lands. Parks Canada's species database lists it as a native species of highest concern (status rank MA1, equivalent to an S1 provincial ranking but applicable to the managed area) in 13 areas including Point Pelee, Thousand Islands, and La Mauricie National Parks (Nantel pers. comm. 2016).

Butternut presents a challenge in the identification of Critical Habitat because it is a wide-ranging and locally common species and its main threat (Butternut Canker) is not habitat-related (Environment Canada 2010). As a result, Critical Habitat for the species has yet to be identified. The federal recovery strategy (Environment Canada 2010) includes a proposed schedule for research activities necessary for the identification of Critical Habitat, with a targeted completion date of 2019. In the interim, Butternut does not receive habitat protection under the federal *Species at Risk Act*.

The Province of Ontario has prepared a provincial recovery strategy (Poisson and Ursic 2013), which consists of the federal recovery strategy (Environment Canada 2010) with additional recommendations pertaining to habitat regulations. The document identifies general habitat as suitable areas within a 50 m radius around the trunk and proposes that habitat protection include a minimum radius of 25 m around the base of the stem irrespective of the tree's size. It advises that this protection should only be granted to "healthy" trees, and that areas covered by impervious surfaces (e.g., paved roads, sidewalks, buildings) as a result of existing and approved land uses be excluded from the regulated area. These recommendations have not yet been put into force.

Some Butternut habitat receives indirect protection from various provincial laws and policies pertaining to shoreline development, wetland and riparian buffers, and the protection of watercourses.

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## **BIOGRAPHICAL SUMMARY OF REPORT WRITERS**

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

Sean Blaney is the Executive Director and Senior Scientist of the AC CDC, where he is responsible for maintaining status ranks and a rare plant occurrence database for plants in each of the three Maritime provinces. Since beginning with the AC CDC in 1999, he has discovered dozens of new provincial records for vascular plants and documented over 15,000 rare plant occurrences during extensive fieldwork across the Maritimes. Sean is a member of the COSEWIC Vascular Plant Species Specialist Committee and the Nova Scotia Atlantic Coastal Plain Flora Recovery Team, and has authored or co-authored numerous COSEWIC and provincial status reports. Prior to employment with AC CDC, Sean received a BSc in Biology (Botany Minor) from the University of Guelph and an MSc in Plant Ecology from the University of Toronto, and worked on a number of biological inventory projects in Ontario as well as spending eight summers as a naturalist in Algonquin Park, where he co-authored the second edition of the park's plant checklist.

## **COLLECTIONS EXAMINED**

No collections were examined for the preparation of this status report.

## Appendix 1: Threats Classification Table for Butternut (*Juglans cinerea*).

| THREATS ASSESSMENT WORKSHEET                   |           |  |                                     |
|--|-----------|--|-------------------------------------|
| <b>Species or Ecosystem Scientific Name</b>    |           | Butternut - <i>Juglans cinerea</i>   |                                     |
| <b>Element ID</b>                              |           | <b>Elcode</b>  |                                     |
| <b>Date (Ctrl + ";" for today's date):</b>     |           | 26/09/2016   |                                     |
| <b>Assessor(s):</b>                            |           | Dwayne Lepitzki, Del Meidinger, Bruce Bennett, Sean Blaney, David Mazerolle, Karen Timm, Jacques Labrecque, Mary Sabine, Ruben Boles, Julie Nadeau, Dan Brunton, Sue Meades, Vivian Brownell, Barb Boysen, Tannis Beardmore, Rose Fleguel, Richard Wilson, Eric Snyder |                                     |
| <b>References:</b>                             |           |  |                                     |
| <b>Overall Threat Impact Calculation Help:</b> |           |  | <b>Level 1 Threat Impact Counts</b> |
| <b>Threat Impact</b>                           |           |  | <b>high range</b>                   |
| <b>low range</b>                               |           |  |                                     |
| A  | Very High | 1  | 1                                   |
| B  | High      | 0  | 0                                   |
| C  | Medium    | 0  | 0                                   |
| D  | Low       | 3  | 3                                   |
| <b>Calculated Overall Threat Impact:</b>       |           | <b>Very High</b>   | <b>Very High</b>                    |
| <b>Assigned Overall Threat Impact:</b>         |           | <b>A = Very High</b>   |                                     |
| <b>Impact Adjustment Reasons:</b>              |           |  |                                     |
| <b>Overall Threat Comments</b>                 |           | Generation time is 45 years; timing is 10 yrs or 3 gens, whichever is longer; 3 generations = 135 years. Based on current knowledge and EOs, ~41% in ON, ~44.8% in QC, and ~14.2% in NB  |                                     |

| Threat                                 | Impact (calculated) | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing            | Comments  |
|--|---------------------|---------------------|-----------------------------|-------------------|---|
| 1 Residential & commercial development | D Low               | Small (1-10%)       | Extreme (71-100%)           | High (Continuing) |   |
| 1.1 Housing & urban areas              | D Low               | Small (1-10%)       | Extreme (71-100%)           | High (Continuing) | Overall, group agrees that scope is closer to the lower end of this range in Canada. There is some mitigation in place when trees are taken down but there is the possibility that hybrids are the replaced tree, which would be a further threat. Some low level small targeted harvesting of trees to remove potential restriction for development. |
| 1.2 Commercial & industrial areas      | Negligible          | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) |   |
| 1.3 Tourism & recreation areas         | Negligible          | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) |   |
| 2 Agriculture & aquaculture            | D Low               | Small (1-10%)       | Extreme (71-100%)           | High (Continuing) |   |

| Threat |  | Impact (calculated) |            | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing            | Comments  |
|--------|--|---------------------|------------|---------------------|-----------------------------|-------------------|---|
| 2.1    | Annual & perennial non-timber crops      | D                   | Low        | Small (1-10%)       | Extreme (71-100%)           | High (Continuing) | Conversion to agricultural land; in NB the issue is with potato crop. In SW and SE ON there is a lot of conversion to agricultural land but don't have the data. Also, some abandonment of agricultural land which may convert back to forest.  |
| 2.2    | Wood & pulp plantations                  |                     |            |                     |                             |                   |   |
| 2.3    | Livestock farming & ranching             |                     |            |                     |                             |                   |   |
| 2.4    | Marine & freshwater aquaculture          |                     |            |                     |                             |                   |   |
| 3      | Energy production & mining               |                     | Negligible | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) |   |
| 3.1    | Oil & gas drilling                       |                     |            |                     |                             |                   |   |
| 3.2    | Mining & quarrying                       |                     | Negligible | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) | Quarrying for aggregate does occur in the range of Butternut. Pressure in S ON for aggregate. The species does tend to concentrate in these types of habitat. In QC there is quarrying on limestone but scope was uncertain. In NB, is more sand/gravel than hard rock quarrying and impact would be very small overall. There are some sites where the impact may be higher (R. Fleguel) |
| 3.3    | Renewable energy                         |                     | Negligible | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) | More impact from solar than wind farms in ON.   |
| 4      | Transportation & service corridors       |                     | Negligible | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) |   |
| 4.1    | Roads & railroads                        |                     | Negligible | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) |   |
| 4.2    | Utility & service lines                  |                     | Negligible | Negligible (<1%)    | Extreme (71-100%)           | High (Continuing) |   |
| 4.3    | Shipping lanes                           |                     |            |                     |                             |                   |   |
| 4.4    | Flight paths                             |                     |            |                     |                             |                   |   |
| 5      | Biological resource use                  | D                   | Low        | Small (1-10%)       | Extreme - Serious (31-100%) | High (Continuing) |   |
| 5.1    | Hunting & collecting terrestrial animals |                     |            |                     |                             |                   |   |
| 5.2    | Gathering terrestrial plants             |                     | Negligible | Negligible (<1%)    | Negligible (<1%)            | High (Continuing) | Harvesting of nuts for consumption, and collection of juglone for medical purposes was discussed but was of negligible impact overall. Removal of nuts does decrease recruitment potential.   |

| Threat |  | Impact (calculated) |              | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.)  | Timing            | Comments   |
|--------|--|---------------------|--------------|---------------------|------------------------------|-------------------|--|
| 5.3    | Logging & wood harvesting                    | D                   | Low          | Small (1-10%)       | Extreme - Serious (31-100%)  | High (Continuing) | Some low level small targeted harvesting in anticipation of mortality (counted above in urban and rural development), as well as general wood harvesting. Incidental harvesting could help recruitment. Informal cutting of trees for firewood was discussed. Incidental harvesting is ongoing. Some targeted logging with associated permits. |
| 5.4    | Fishing & harvesting aquatic resources       |                     |              |                     |                              |                   |  |
| 6      | Human intrusions & disturbance               |                     | Negligible   | Negligible (<1%)    | Slight (1-10%)               | High (Continuing) |  |
| 6.1    | Recreational activities                      |                     |              |                     |                              |                   |  |
| 6.2    | War, civil unrest & military exercises       |                     | Negligible   | Negligible (<1%)    | Slight (1-10%)               | High (Continuing) | Some Butternut on CFB Gagetown and there is possibility of incidental destruction. UXO at Ipperwash work ongoing. Overall of trivial impact as are on federal lands.   |
| 6.3    | Work & other activities                      |                     | Not a Threat | Negligible (<1%)    | Neutral or Potential Benefit | High (Continuing) | Research ongoing on this or other species in same habitat which may be beneficial to population in long term. Collection of nuts for cryo-storage or propagation was discussed.  |
| 7      | Natural system modifications                 |                     | Unknown      | Unknown             | Unknown                      | High (Continuing) |  |
| 7.1    | Fire & fire suppression                      |                     |              |                     |                              |                   |  |
| 7.2    | Dams & water management/use                  |                     |              |                     |                              |                   | Mataquac Dam in NB (and likely others) will be reaching end of life and decisions (likely replacement) will be made in next 10 years. There may be impacts for this riparian species but they are uncertain at this time (may actually be positive).   |
| 7.3    | Other ecosystem modifications                |                     | Unknown      | Unknown             | Unknown                      | High (Continuing) | Movement into a lower disturbance regime on a landscape scale may affect this species in the long term. May result in a lack of recruitment. However, blowdowns and informal disturbance (trails) may offer positive benefits. Invasive species, like Common Buckthorn, could limit habitat for regeneration.                                  |
| 8      | Invasive & other problematic species & genes | A                   | Very High    | Pervasive (71-100%) | Extreme (71-100%)            | High (Continuing) |  |

| Threat |                                   | Impact (calculated) |           | Scope (next 10 Yrs)         | Severity (10 Yrs or 3 Gen.) | Timing            | Comments  |
|--------|-----------------------------------|---------------------|-----------|-----------------------------|-----------------------------|-------------------|---|
| 8.1    | Invasive non-native/alien species | A                   | Very High | Pervasive (71-100%)         | Extreme (71-100%)           | High (Continuing) | Foremost threat is Butternut Canker, a lethal disease caused by the fungal pathogen <i>Ophiognomonia clavignenti-juglandacearum</i> . Butternut Canker kills trees of all ages. Saplings are often quickly killed, while mature trees may survive many years before dying from severe crown loss and girdling by coalescing stem cankers. Field observations suggest >90% of population infected; resistant trees rare and often hybrids. Also suppresses regeneration. Mortality >80% observed in some areas. In Canada, Butternut Canker was first collected in Quebec in 1990 and then detected in Ontario in 1991 and in New Brunswick in 1997. Rates of infection and mortality are not presently well understood in Canada but given 3 generations, available data, personal observations and anecdotal information all suggest that rates will be comparable to those documented in the United States. High rates of mortality in US. NOTE infection estimates of 13 000 trees need to be considered carefully so that context is clear. Some disagreement as to what population estimate should be overall. |
| 8.2    | Problematic native species        |                     | Unknown   | Restricted - Small (1-30%)  | Unknown                     | High (Continuing) | Browsing by White-tailed Deer -- threat where deer in high population density. White-tailed Deer target Butternut but may be a local issue.   |
| 8.3    | Introduced genetic material       |                     | Unknown   | Large - Restricted (11-70%) | Unknown                     | High (Continuing) | <i>J. x bixbyi</i> , produced by hybridization with Japanese walnut, a species widely cultivated in North America over the last century. Hybrids believed to be self-fertile and able to cross with other hybrids and backcross with parent taxa. Hybrid trees are highly vigorous, high yielding and have greater resistance to Butternut Canker. Extensive hybridization and recurrent backcrossing could threaten the genetic integrity of affected population. Hybridization is indeed a threat to the pure species, but may be of benefit to the survival (due to resistance to canker by hybrids) of a future species (however hybridized) down the road.   |

| Threat |                                      | Impact (calculated) |         | Scope (next 10 Yrs) | Severity (10 Yrs or 3 Gen.) | Timing     | Comments  |
|--------|--------------------------------------|---------------------|---------|---------------------|-----------------------------|------------|---|
| 9      | Pollution                            |                     |         |                     |                             |            |   |
| 9.1    | Household sewage & urban waste water |                     |         |                     |                             |            |   |
| 9.2    | Industrial & military effluents      |                     |         |                     |                             |            |   |
| 9.3    | Agricultural & forestry effluents    |                     |         |                     |                             |            |   |
| 9.4    | Garbage & solid waste                |                     |         |                     |                             |            |   |
| 9.5    | Air-borne pollutants                 |                     |         |                     |                             |            |   |
| 9.6    | Excess energy                        |                     |         |                     |                             |            |   |
| 10     | Geological events                    |                     |         |                     |                             |            |   |
| 10     | Volcanoes                            |                     |         |                     |                             |            |   |
| 10     | Earthquakes/tsunamis                 |                     |         |                     |                             |            |   |
| 10     | Avalanches/landslides                |                     |         |                     |                             |            |   |
| 11     | Climate change & severe weather      |                     | Unknown | Pervasive (71-100%) | Unknown                     | High - Low | Changes acting synergistically with other threats. No clear evidence of climate change effects on this species or its habitat at this time. |
| 11     | Habitat shifting & alteration        |                     |         |                     |                             |            |   |
| 11     | Droughts                             |                     |         |                     |                             |            |   |
| 11     | Temperature extremes                 |                     |         |                     |                             |            |   |
| 11     | Storms & flooding                    |                     |         |                     |                             |            |   |

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