A survey of tree species of concern in Canada: the role for genetic conservation

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ABSTRACT

A survey was conducted in 2003 to identify Canadian native tree species (woody perennials ≥10 m tall) that may be in need of genetic conservation. Thirty expert respondents from various agencies in provinces and territories graded the tree species in their respective geographical regions based on nine criteria that describe potential reasons for conservation (e.g., rarity, decreasing range or frequency, preferred habitat in high demand, uncertain viable seed source) and then provided a rating that identifies the type of conservation that may be required (species is in good shape, insufficient knowledge for a designation, *in situ* or *ex situ* conservation measures are required). Either *in situ* or *ex situ* conservation was recommended for 52% of Canada's native tree species, and 8% required more information before a rating could be made. The results of the survey will be used to identify genetic conservation priorities for tree species in Canada.

Key words: Canadian tree species of concern, genetic conservation, genetic diversity, species rarity

RÉSUMÉ

En 2003, on a procédé à une enquête dans le but d'identifier les espèces d'arbres indigènes canadiennes (vivaces ligneuses atteignant 10 m et plus) qui pourraient faire l'objet de conservation génétique. Trente répondants experts de divers agences dans les provinces et territoires ont classé les espèces d'arbre présentes dans leur propre région géographique selon neuf critères qui décrivent des raisons possibles pour la conservation (par ex., rareté de l'espèce, réduction de l'étendue ou de l'occurrence, habitat préféré en grande demande, source de semences viables incertaine), et ont ensuite déterminé, par l'attribution d'une cote, les actions de conservation appropriées (maintenir l'espèce en bon état, accroître les connaissances pour attribuer une désignation, appliquer des mesure de conservation *in situ* ou *ex situ*). La conservation *in situ* ou *ex situ* a été recommandée pour 52 % des espèces d'arbre indigènes du Canada, et pour 8 % des espèces, il y aurait lieu d'accroître les connaissances avant de les classer dans une désignation. Les résultats de cette enquête serviront dans la détermination des actions à privilégier en matière de conservation des espèces d'arbres indigènes au Canada.

Mots clés : espèces d'arbre en situation préoccupante au Canada, conservation génétique, diversité génétique, rareté d'espèce

Introduction

Forest ecosystems in Canada contain approximately 124 native tree species, depending on the definition of large shrub vs. small tree (Farrar 1995). These forests, which cover approximately half of Canada, face a variety of threats, including land-use changes, environmental change, invasive alien species (IAS), and harvesting practices that ignore silvicultural requirements of non-commercial species. Given the size of these forests and their diversity, obtaining a Canadian perspective on how individual tree species are tolerating these threats is challenging. Although most tree species in Canada are in no danger of extinction or local extirpation, loss of populations with unique alleles or combination of alleles does occur (Namkoong 1989). This is sometimes referred to as hidden extinction, and can have adverse consequences for long-term species viability.

Genetic conservation refers to preserving the evolutionary potential of species and populations to allow for adaptation to environmental change. In practice, this usually means conserving genetic diversity as well as the genetic processes that maintain diversity. Maintaining diverse gene pools of native species takes on increased importance in light of land-use demands, climate change, introductions of invasive exotic species, and other challenges to forest ecosystems. Genetic conservation is carried out by identifying the threats to genetic diversity, understanding species biology and ecology, and developing management strategies and objectives for populations, usually with a combination of *ex situ* (out of place, including germplasm collections) and *in situ* (in place, including protected areas and altered forestry practices) methods. Although genetic conservation is a concept with a long history, little effort has been focused on its implementation in management practices.

The work reported here identified tree species that may be in need of genetic conservation. The data will aid the Canadian Forest Service (CFS) National Tree Seed Centre to rank the species from which seeds are collected and preserved in long-term storage. The CFS National Forest Genetic Resources Centre (NFGRC) conducted the survey as a first step to identify priority tree species requiring genetic conserva-

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tion. Several provinces are actively pursuing programs to identify species requiring genetic conservation measures, or to develop and implement strategies for a variety of species. The purpose of the present study is not to duplicate on-going conservation efforts, but to provide a national perspective on the need for the genetic conservation of tree species across the country, determine how these species' needs are presently being met, and identify what areas need more work. The survey was sent to experts from various agencies in all provinces and territories asking them to comment on conservation needs for a provided list of species. We asked them to add any missing species that require or may require conservation attention. The information obtained by the survey and summarized here represents a first collaborative effort of various experts across the country.

Survey Methodology

Development of the survey

The initial list of Canadian native tree species included all native species described in *Trees in Canada* (Farrar 1995) either pictorially as 10 m or greater or, stated in the text as equal to or exceeding 10 m in height when mature. This list contained 124 tree species.

Databases from various sources, including conservation data centers (CDCs), provincial resource departments and their species-at-risk lists, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and others, were searched to identify tree species of potential concern for each Canadian provincial or territorial jurisdiction. We used a set of criteria (Table 1), adapted from the New Brunswick Gene Conservation Working Group (Powell and Beardmore 2002) to identify species that may require genetic conservation measures.

Using the available databases, tentative criteria (9) and rating values (RV0–RV3) were assigned by province or territory for each tree species by the authors. The survey was sent to 42 experts from government, universities, and non-governmental organizations in each province and territory. These experts were asked to use the proposed criteria and ratings to assess the species list for accuracy and completeness, and to assign criteria and ratings to any additional species in their jurisdiction that require gene conservation.

Evaluation of survey results

In total, 30 people from all jurisdictions except Yukon Territory, responded to the survey, and provided revised species lists. We adjusted our ratings according to the most rigorous assessments provided by jurisdictional experts. The survey results were collated for each province and territory, and the revised species list for each jurisdiction was emailed to participants for a second round of consultations, resulting in consensus on the criteria and ratings. In some cases, respondents identified varieties that may be in need of conservation. This information is presented. However, it should be noted that the total number of native tree varieties in Canada is not known, so we are unable to provide a percentage of total number of varieties.

The data from each province and territory were amalgamated into a single data set, and sorted by genus. This allowed us to evaluate the frequency with which a given species was given a rating greater than 0. Species were often assigned different ratings in different jurisdictions, depending on their status for a particular province or territory. To simplify summarizing some aspects of the survey, we only considered the highest rating value to represent a threat to the species' conservation status. It is important to recognize that the rating for a given species often refers only to a portion of the species' range.

Recognizing that species and ecosystems are naturally distributed following ecological boundaries, not political ones, ecozones were identified within the natural range of each species requiring conservation. This was done by visually comparing species range maps (Burns and Honkala 1990a, b) with ecozone maps (Canadian Council on Ecological Areas 1996).

Table 1. System used to list species in need of conservation first by a) descriptive criteria and then by b) rating values

a) Criteria	Description
1	Species rarity is a concern.
2	There is no or an uncertain viable seed source.
3	There is a serious threat from an exotic disease or insect.
4	There is a serious threat as a result of environmental change.
5	Certain harvesting practices prevent the regeneration of the species.
6	The range or frequency of the species is substantially decreasing.
7	The preferred habitat of the species is in high demand for other uses.
8	There is a high demand for the species for a special purpose.
9	The species is threatened because of hybridization or introgression.
b) Rating Value	**Description**
0	The species is considered to be in good shape with no apparent cause for concern.
1	The species may need attention but current knowledge is inadequate due to: a) insufficient data; b) direct evidence of a potential problem; c) indirect evidence of a potential problem.
2	The species requires *in situ* conservation.
3	Specific gene conservation measures (*ex situ*) are required to ensure the integrity of the native gene pool.

Summary of Causes of Concern

Based on the results of the survey, seven varieties were added to the final list of 124 native tree species (Table 2). Of these, 77 species and six varieties were identified in at least one province or territory as requiring some level of genetic conservation or additional information to determine whether conservation efforts are required (Table 2). In particular, 47 species and three varieties require specific *ex situ* genetic conservation measures (RV3), 20 species require *in situ* conservation (RV2), and 10 species and four varieties may need atten-

Table 2. Native trees of Canada and conservation requirements

Genus	Common names	Number of Species	Nyber of Species in need of conservation	Species names (rating values (RV) in brackets[a])
Conifers				
Abies	Fir	4	1	*amabilis, balsamea, grandis* (2), *lasiocarpa*
Chamaecyparis	Cypress	1	0	*nootkatensis*
Juniperus	Juniper	2	2	*scopulorum* (2), *virginiana* (2)
Larix	Larch	3	3	*laricina* (1,2), *lyallii* (1), *occidentalis* (3)
Picea	Spruce	5	1	*engelmannii, glauca, mariana, rubens* (3), *sitchensis*
Pinus	Pine	9	7	*albicaulis* (3), *banksiana* (2,3), *contorta, flexilis* (2,3), *monticola* (3), *ponderosa, resinosa* (3), *rigida* (2), *strobus* (3)
Pseudotsuga	Douglas-fir	1	0	*menziesii* [var. *gl*auca, var. *menziesii*]
Taxus	Yew	1	1	*brevifolia* (2)
Thuja	Cedar	2	2	*occidentalis* (3), *plicata* (3)
Tsuga	Hemlock	3	2	*canadensis* (1a,2), *heterophylla* (3), *mertensiana*
Summary totals		10 genera; 31 species	8 genera (80%); 19 species (61%)	RV of 1 or 1a: 1 species RV of 2: 7 species RV of 3: 10 species
Hardwoods				
Acer	Maple	10	1	*circinatum, glabrum, macrophyllum, negundo* (1a,2) [var. *negundo* (1a), var. *violaceum* (1a)], *nigrum, pensylvanicum, rubrum*, s*accharinum, saccharum, spicatum*
Aesculus	Buckeye	1	1	*glabra* (2)
Alnus	Alder	4	0	*rubra, rugosa*, [syn. *incana* ssp. *rugosa*], *sinuata* [syn. *viridis* ssp. *sinuata*], *incana* ssp. *tenuifolia* [syn. *tenuifolia*]
Arbutus	Arbutus	1	1	*menziesii* (1a,2)
Asimina	Pawpaw	1	1	*triloba* (2,3)
Betula	Birch	6	3	*alleghaniensis* (3), *cordifolia* (1a), *lenta* (3), *neoalaskana, occidentalis* (3), *papyrifera* [var. *cordifolia* (1a)], *populifolia*
Carpinus	Blue beech	1	1	*caroliniana* (2)
Carya	Hickory	4	2	*cordiformis, glabr*a [var. *odorata* (3)], *laciniosa* (2,3), *ovata* (2)
Castanea	Chestnut	1	1	*dentata* (3)
Celtis	Hackberry	1	1	*occidentalis* (2)
Cercis	Redbud	1	0	*canadensis*[b]
Cornus	Dogwood	3	1	*alternifolia* (2,3), *florida, nuttallii* (1a)
Crataegus	Hawthorns	4	0	*coccinea* (1a), *crus-galli* (1a), *douglasii* (1a), *mollis*
Fagus	Beech	1	1	*grandifolia* (3)
Fraxinus	Ash	5	5	*americana* (3), *nigra* (3), *pennsylvanica* (3), *profunda* (3), *quadrangulata* (3)
Gleditsia	Honey Locust	1	1	*triacanthos* (3)
Gymnocladus	Kentucky Coffee-tree	1	1	*dioicus* (3)
Hamamelis	Witch Hazel	1	1	*virginiana* (2,3)
Juglans	Walnut	2	2	*cinerea* (3), *nigra* (3)
Liriodendron	Tulip-tree	1	1	*tulipifera* (3)
Magnolia	Cucumber tree	1	1	*acuminata* (3)
Malus	Wild Apple	2	0	*coronaria, fusca*
Morus	Mulberry	1	1	*rubra* (3)
Nyssa	Black gum	1	1	*sylvatica* (3)
Ostrya	Ironwood	1	0	*virginiana*
Platanus	Sycamore	1	0	*occidentalis*
Populus	Poplar	6	4	*angustifolia* (1a,2), *balsamifera* (1a,2), *deltoides* (2,3) [var. *deltoides* (2,3), var. *occidentalis* (2,3)], *grandidentata* (3), *tremuloides, trichocarpa*
Prunus	Cherry	6	1	*americana, emarginata, nigra* (3), *pensylvanica, serotina* (1a), *virginiana* [var. *virginiana* (1a)]
Ptelea	Hop-tree	1	1	*trifoliata* (2)

Table 2. (continued)

Genus	Common names	Number of Species	Number of Species in need of conservation	Species names (rating values (RV) in brackets[a])
Hardwoods (con't)				
Quercus	Oak	11	10	*alba* (2), *bicolor* (2), *ellipsoidalis* (2,3), *garryana* (2,3), *macrocarpa* (1a, 3), *muehlenbergii* (3), *palustris* (2,3), *prinoides* (2,3), *rubra* (3), *shumardii* (2,3), *velutina* (1a)
Rhamnus	Buckthorn	1	0	*purshiana*
Salix	Willow (trees only)	2	2	*amygdaloides* (3), *nigra* (3)
Sambucus	Elder	2	0	*cerulea*, *glauca*
Sassafras	Sassafras	1	0	*albidum*
Sorbus	Mountain Ash	2	0	*americana*, *decora* (1a)
Tilia	Basswood	1	1	*americana* (1a,2)
Ulmus	Elm	3	3	*americana* (3), *rubra* (3), *thomasii* (2)
Summary totals		37 genera 93 species	26 genera (70%) 50 species (54%)	RV of 1a[c]: 9 species, 4 varieties RV of 2[c]: 132 species, 0 varieties RV of 3[c]: 37 species, 3 varieties

[a]Ratings values refer to the highest score for the species within its range in Canada. Those species listed without a number in brackets received either a rating of 0 (species is considered to be in good shape) or no rating was given, so the assumption was made that there is no concern for this species.
[b]This species is most likely extirpated.
[c]Only the highest RV for a species is considered for these summary values.

tion, but insufficient knowledge is currently available (RV 1 or 1a) (Table 2). Note that a number of species received two or more rating values and only the highest RV is considered for those summary values.

In examining why there is a need for conservation, natural rarity is the predominant reason for a species listing (59 species, two varieties), followed by substantial decrease in the range or frequency of a species (32 species, two varieties), preferred habitat of the species in high demand for other uses (31 species, two varieties), uncertain viable seed source (29 species, two varieties), harvesting and management practices affecting regeneration (26 species, one variety), and exotic disease or pest problems (19 species) (Table 3). Only eight species and one variety were listed because of concerns about hybridization or introgression, five species were listed because of a high demand for special purposes and four species and one variety were listed because of environmental change.

Multiple criteria were listed for numerous species, which is expected as many of the reasons for identifying a species as one of concern are interrelated. For example, "rarity" or "limited spatial distribution" may be the result of a contributing factor to other criteria, such as hybridization or introgression, or high demand for special purpose. *Castanea dentata* is an example of a species listed under multiple criteria (criteria 1, 2, 3, and 9, Table 3). This species, which was once a dominant forest species in southern Ontario, has been all but eliminated by chestnut blight (*Cryphonectira parasitica*). There is evidence that hybridization has occurred in the remaining trees, and long-term seed storage is not possible (COSEWIC 2002).

Population decline

Criterion 6, "range or frequency of species is substantially decreasing," is very broad, and most respondents did not list a reason for the decline other than low recruitment (e.g., *Aesculus glabra*, *Gymnocladus dioicus*, *Quercus muehlenbergii*) and moose browsing (*Betula lenta*). The reasons for listing a species under criterion 7, "preferred habitat of the species in high demand for other uses," were either agricultural land clearing (e.g., *Quercus ellipsoidalis*) or housing (*Liriodendron tulipifera*) and cottage development (e.g., *Quercus macrocarpa*, *Thuja occidentalis*). Criterion 5, "harvesting practices prevent regeneration," usually refers to incidental effects of harvesting (i.e., the forest is managed for regeneration of a particular commercial species and the species that are affected negatively are generally not commercially important so they may be "invisible" to managers). Only five species were listed under criterion 8, "high demand for special purposes" (*Fraxinus nigra*, which is highly valued in Aboriginal communities for basket making, *Juglans cinerea* and *Pinus strobus*, which are used for furniture and cabinet making, *Taxus brevifolia*, which contains an anti-cancer compound, taxol, and *Thuja occidentalis*, which is used for specialty items such as log cabins and canoes (Burns and Honkala 1990a, b)).

The reasons for a species listing under criterion 4, "environmental change," specifically dealt with changes in hydrology. For *Quercus shumardii* and *Carya laciniosa*, drainage ditches throughout their range in southwestern Ontario have changed the hydrology, and as a result, little natural recruitment occurs. *Populus deltoides* and *P. angustifolia* were listed under environmental change because of a change in habitat caused by dams.

Lack of reproduction

Criterion 2, "uncertain seed source," refers to a situation where seed crops are not abundant, e.g., because of low fecundity and seed set (*Gymnocladus dioicus*, *Morus rubra*, *Liriodendron tulipifera*) (Burns and Honkala 1990b, Hong *et al.* 1998). This assessment may be made by directly assessing the seed crop or by the lack of successful regeneration. Other species listed under this criterion include *Betula lenta*,

Table 3. Reasons for tree species listing as ones of concern based on criteria values (CV)[a]

Abiotic Reasons	Summary
a) Rarity (criterion 1): *Abies grandis, Acer negundo, Acer nigrum, Aesculus glabra, Asimina triloba, Betula alleghaniensis, Betula cordifolia, Betula lenta, Betula occidentalis, Carya glabra* var. *odorata, Carya laciniosa, Castanea dentata, Celtis occidentalis, Cornus alternifolia, Cornus nuttallii, Crataegua coccinea, Crataegus douglasii, Fagus grandifolia, Fraxinus nigra, Fraxinus pennsylvanica, Fraxinus profunda, Fraxinus quadrangulata, Gleditsia triacanthos, Gymnocladus dioicus, Hamamelis virginiana, Juniperus scopulorum, Juniperus virginiana, Larix laricina, Larix lyallii, Larix occidentalis, Liriodendron tulipifera, Magnolia acuminata, Morus rubra, Nyssa sylvatica, Picea rubens, Pinus banksiana, Pinus resinosa, Pinus rigida, Pinus strobus, Populus angustifolia, Populus deltoides* var. *deltoides, Populus grandidentata, Prunus nigra, Ptelea trifoliata, Quercus alba, Quercus bicolor, Quercus ellipsoidalis, Quercus macrocarpa, Quercus muehlenbergii, Quercus palustris, Quercus prinoides, Quercus shumardii, Salix amygdaloides, Salix nigra, Thuja occidentalis, Thuja plicata, Tsuga canadensis, Tsuga heterophylla, Ulmus americana, Ulmus rubra, Ulmus thomasii*	Total # of species: 59 Total # of varieties: 2 # of conifers: 15 # of hardwoods: 46
b) Uncertain viable seed source (criterion 2) : *Aesculus glabra, Asimina triloba, Betula lenta, Carya glabra* var. *odorata, Carya laciniosa, Castanea dentata, Cornus alternifolia, Fraxinus nigra, Fraxinus quadrangulata, Gleditsia triacanthos, Gymnocladus dioicus, Liriodendron tulipifera, Magnolia acuminata, Morus rubra, Nyssa sylvatica, Pinus albicaulis, Pinus banksiana, Pinus rigida, Populus deltoides* var. *deltoides, Ptelea trifoliata, Quercus ellipsoidalis, Quercus garryana, Quercus palustris, Quercus prinoides, Quercus shumardii, Sorbus decora, Thuja occidentalis, Tsuga canadensis, Ulmus americana, Ulmus rubra, Ulmus thomasii*	Total # of species: 29 Total # of varieties: 2 # of conifers: 5 # of hardwoods: 26
c) Range or frequency of species substantially decreasing (criterion 6): *Aesculus glabra, Asimina triloba, Betula lenta, Carpinus caroliniana, Carya glabra* var. *odorata, Carya laciniosa, Carya ovata, Fraxinus americana, Fraxinus nigra, Gleditsia triacanthos, Gymnocladus dioicus, Juglans cinerea, Liriodendron tulipifera, Magnolia acuminata, Morus rubra, Nyssa sylvatica, Picea rubens, Pinus albicaulis, Pinus resinosa, Pinus rigida, Pinus strobus, Populus deltoides* var. *deltoides, Ptelea trifoliata, Quercus ellipsoidalis, Quercus macrocarpa, Quercus palustris, Quercus prinoides, Quercus rubra, Quercus shumardii, Thuja occidentalis, Tsuga canadensis, Ulmus americana, Ulmus rubra, Ulmus thomasii*	Total # of species: 32 Total # of varieties: 2 # of conifers: 7 # of hardwoods: 25
d) Hybridization or integression (criterion 9): *Castanea dentata, Juglans cinerea, Morus rubra, Picea rubens, Populus augustifolia, Populus deltoides* var. *deltoides, Sorbus decora, Ulmus rubra, Ulmus thomasii*	Total # of species: 8 Total # of varieties: 1 # of conifers: 1 # of hardwoods: 8
Biotic Reasons	**Summary**
e) Exotic disease or pest (criterion 3): *Castanea dentata, Fagus grandifolia, Fraxinus americana, Fraxinus nigra, Fraxinus pennsylvanica, Fraxinus profunda, Fraxinus quadrangulata, Juglans cinerea, Magnolia acuminata, Pinus albicaulis, Pinus flexilis, Pinus monticola, Pinus resinosa, Pinus strobus, Quercus macrocarpa, Tsuga canadensis, Ulmus americana, Ulmus rubra, Ulmus thomasii*	Total # of species: 19 Total # of varieties: 0 # of conifers: 6 # of hardwoods: 13
f) Environmental change (criterion 4): *Carya laciniosa, Populus angustifolia, Populus deltoides, Populus deltoides* var. *occidentalis, Quercus shumardii*	Total # of species: 4 Total # of varieties: 1 # of conifers: 0 # of hardwoods: 5
g) Harvesting practices prevent regeneration (criterion 5): A*esculus glabra, Asimina triloba, Betula lenta, Carya glabra* var. *odorata, Carya laciniosa, Fraxinus americana, Gleditsia triacanthos, Gymnocladus dioicus, Larix occidentalis, Magnolia acuminata, Nyssa sylvatica, Picea rubens, Pinus banksiana, Pinus resinosa, Pinus rigida, Populus deltoides, Ptelea trifoliata, Quercus ellipsoidalis, Quercus muehlenbergii, Quercus palustris, Quercus prinoides, Quercus shumardii, Taxus brevifolia, Thuja occidentalis, Tsuga canadensis, Ulmus rubra, Ulmus thomasii*	Total # of species: 26 Total # of varieties: 1 # of conifers: 8 # of hardwoods: 19
h) Preferred habitat of the species in high demand for other uses (criterion 7): *Aesculus glabra, Asimina triloba, Betula lenta, Carpinus caroliniana, Carya glabra* var. *odorata, Carya laciniosa, Carya ovata, Fraxinus americana, Gleditsia triacanthos, Juglans cinerea, Juglans nigra, Larix occidentalis, Liriodendron tulipifera, Magnolia acuminata, Nyssa sylvatica, Pinus albicaulis, Pinus rigida, Pinus strobus, Populus angustifolia, Populus deltoides* var. *deltoides, Ptelea trifoliata, Quercus bicolor, Quercus ellipsoidalis, Quercus garryana, Quercus muehlenbergii, Quercus prinoides, Quercus shumardii, Thuja occidentalis, Thuja plicata, Tsuga canadensis, Ulmus americana, Ulmus rubra, Ulmus thomasii*	Total # of species: 31 Total # of varieties: 2 # of conifers: 7 # of hardwoods: 26
i) High demand for special purpose (criterion 8): *Fraxinus nigra, Juglans cinerea, Pinus strobus, Taxus brevifolia, Thuja occidentalis*	Total # of species: 5 Total # of varieties: 0 # of conifers: 3 # of hardwoods: 2

[a]In certain geographical areas these species may be listed as of concern. A species may have more than one criterion and therefore be listed under a number of headings.

Table 4. Canadian tree species in need of conservation as a result of an identified pest or pathogen

Pathogen or pest	Genus and or species of primary hosts	Estimated mortality due to pest or pathogen	Control at a population level	Natural resistance within the species
Fungus				
Beech bark disease* (*Nectria coccinea* with *Cryptococcus fagisuga*)	*Fagus grandifolia*	> 85%[a]	no	yes[b]
Butternut canker* (*Sirococcus clavigignenti juglandacearum*)	*Juglans cinerea*	> 90%[c]	no	unknown
Chestnut blight* (*Cryphonectria parasitica*)	*Castenea dentata*	> 90%[d]	no	no
Dutch elm disease* (*Ophiostoma novo-ulmi*)	*Ulmus americana, U. rubra, U. thomasii*	70%[e]	no	potentially
Sudden oak death[f] (*Phytophthora ramorum*)	*Quercus* subgenus *Erythrobalanceus* (red oaks)	40–80%[g]	no	unknown
White pine blister rust* (*Cronartium ribicola)*	*Pinus* subgenus *Haploxylon* (five-needle pines), including *P. strobus, P. albicaulis, P. flexilis, P. monticola*	21%[h]	no	yes[i]
Scleroderris canker* *Gremmeniella abietina* (European stain) – *Scleroderris lagerbergii* (native strain)	*Pinus resinosa*	na	no	potentially
Insect				
Emerald ash borer* (*Agrilus planipennis*)	*Fraxinus* ssp.	66–94%[j]	no	unknown
Magnolia scale (*Neolecanium cornuparvum*)	*Magnolia acuminata*	na	yes[k]	no
Hemlock Woolly adelgid* (*Adelges tsugae*)	*Tsuga canadensis*	na	no	no
Pale-winged grey moth (*Iridopsis ephyraria*)	*Tsuga canadensis*	na	yes[l]	no

[a]Houston 1997
[b]1–5% of trees have bark characteristics that are resistance to beech scale infestations (Ohio Department of Natural Resources 2004)
[c]Ontario Ministry of Natural Resources 1997
[d]Anagnostakis 2001
[e]British Broadcasting Corporation 2001
[f]It is uncertain whether Sudden oak death is an exotic or native species to North America (Svihra 2001).
[g]Cohen and Venette 2005
[h]21% is for *Pinus albicaulis*, white bark pine mortality (Campbell and Antos 2000)
[i]Resistant *Pinus monticola* and *P. strobus* have been identified (Hunt and Meagher 1989).
[j]Mastro and Reardop 2004
[k]Shetlar 2003
[l]Nova Scotia Department of Natural Resources, News Release June 13, 2005
*exotic species

Castenea dentata, *Juglans cinerea*, *Magnolia acuminate*, *Quercus* spp. Interestingly, *Castenea dentata*, *Juglans cinerea*, *Magnolia acuminate*, and *Quercus* spp. produce seed, which is intolerant of low temperatures and desiccation (Hong *et al.* 1998). Therefore, an uncertain seed source may be related to the inability of these seed to survive the winter.

Pests and diseases

For criterion 3, "threat from exotic diseases and pests," respondents mentioned seven fungal diseases and four insects. Two of the insects were native (magnolia scale and pale-winged grey moth) and one pathogen (sudden oak death) is of uncertain origin (Table 4). The pale-winged grey moth was not previously known to cause damage to forest tree species, and there is speculation that the increase in this threat is related to stress caused by a series of drier than usual summers. The species listed by respondents as being affected by a disease or pest include all *Fraxinus* and *Ulmus* species native to Canada, as well as *Fagus grandifolia*, *Juglans cinerea*, *Castenea dentata*, *Pinus resinosa*, *Magnolia acuminata*, and *Tsuga canadensis*. In addition, climate change will likely result in more hospitable habitats for a wider range of exotic diseases and pests.

Control at the population level currently exists only for magnolia scale (Shetlar 2003) and pale-winged grey moth (Krischik and Davidson 2000) (Table 4), and natural resistance is found at low levels in four species: *Fagus grandifolia* (Houston 1997) for beech scale, and *Pinus albicaulis* (Hoff *et al.* 2001), *Pinus monticola*, and *P. strobus* (Bingham 1972, Hunt and Meagher 1989) for white pine blister rust.

Survey respondents identified sudden oak death as a fungal disease that may result in high mortality of red oaks (*Quercus* subgenus *Erythrobalanceus* spp.) (Rizzo and Garbelotto 2003). This disease was first detected in 1993 in California, and has not been identified on any native or exotic *Quercus* spp. in Canada (Canadian Food Inspection Agency (CFIA 2003)). However, the fungus was found in British Columbia on a rhododendron imported from the United States (CFIA 2003), and it is present on *Quercus* spp. just south of British Columbia in Oregon (Rizzo and Garbelotto 2003), so it is likely that it will spread to Canadian *Quercus* spp. *Quercus garryana*, a member of the white oak family (subgenus *Lepidobalanus*), is the only native oak in British Columbia. Therefore, sudden oak death is more likely to have an impact on *Quercus* spp. in central and eastern Canada (*Quercus ellipsoidalis*, *Q. palustris*, *Q. rubra*, *Q. shumardii*, *Q. velutina*). The rate of introduction of exotic pests and pathogens is increasing in step with global trade. The stress from exotics, compounded with climate change, will most likely increase in the future. In addition, there are numerous challenges in monitoring the points of entry into the country for intentional and unintentional introductions.

Hybridization and introgression

Criterion 9, "species is threatened because of hybridization or integression," although identified for only a few species, indicates a serious conservation concern, particularly when hybrids are formed between native and exotic species. Over generations, introgression may occur between native and exotic species or between two or more native species (e.g., *Picea rubens* × *Picea mariana*; Perron and Bousquet 1997). Under certain conditions, hybridization may result in higher hybrid fitness than for the native species (e.g., *Populus fremontii* × *Populus angustifolia*; Schweitzer *et al.* 2002). Hybrids may have an advantage in disturbed areas, and the gene pool of the less frequent species may be swamped by that of the more common one. Over time, such a gene pool may lose specific adaptations required to thrive as a pure species in the original habitat. The function of the pure species within its original niche in an ecosystem may also be lost.

Castenea dentata (COSEWIC 2002), *Juglans cinerea* (COSEWIC 2003), and *Morus rubra* (Burgess and Husband 2004) hybridize with exotic species, whereas *Populus angustifolia*, *P. deltoides* (Floate 2004), *Ulmus rubra*, and *Ulmus thomasii* (Smalley and Guries 1993, Burns and Honkala 1990a) hybridize with native and exotic species. *Picea rubens* hybridizes with another native species, *Picea mariana* (Johnsen *et al.* 1998). Hybridization can be beneficial in a tree improvement context for incorporating disease resistance. This is a strategy used for *Castenea dentata* (Hebard 1994) and for some *Ulmus* spp. (Mittempergher and Santini 2004), and it may be adopted for *Juglans cinerea*. However, efforts to hybridize *Ulmus america*na, a tetraploid, with the more resistant Asian or European elms have been challenging because more resistant species are diploid.

Analysis of Problems by Region

In addition to considering the reasons for conservation, it is important to consider whether a species is at risk throughout its range or only in specific areas. Forty-seven out of the 59 species and two varieties where rarity was the reason for the need of conservation are at the very northern limits of their North American ranges (results not shown), and as such, are in need of conservation throughout their limited Canadian range. This includes many tree species found within the Carolinian forest in southern Ontario (e.g., *Castenea dentata*, *Magnolia acuminata*, *Morus rubra*).

In general, the species identified as requiring genetic conservation because an exotic pest caused high mortality were consistently identified throughout the species' range as requiring gene conservation measures (Table 4; results not shown for species distribution). This includes *Castanea dentata*, *Fagus grandifolia*, *Juglans cinerea*, *Ulmus* spp., and *Fraxinus* spp. (Table 4). *Ulmus americana* and *Fraxinus nigra* have the largest ranges, spanning seven provinces (Saskatchewan to Nova Scotia, and Manitoba to Newfoundland, respectively). *Ulmus* spp. were consistently identified throughout their range in seven provinces (Alberta and Ontario east to Newfoundland and Labrador) as requiring specific gene conservation. Dutch elm disease has greatly reduced the number of trees (especially in older age classes) in the three species in this genus over a 60-year period.

In order to account for genetic diversity in adaptive variation in different portions of the species range, survey results are categorized by ecozone rather than political jurisdiction. Ecozones can be used as a first broad proxy for different climatic conditions and other selective pressures that lead to genetic differentiation of species across their range. Canada has 15 ecozones, grouped according to broad physiographic and ecological similarities (Wiken 1986). In examining the number of species in need of conservation by ecozone (species with a RV of 2 or 3), the Mixedwood Plains, which

includes the Carolinian forest in southern Ontario, contains by far the largest number of species (56 species), followed by the Atlantic Maritime (28 species), Boreal Shield (22 species), Boreal Plains (14), Montane Cordillera (12) and Prairies (12) (Table 5). The Pacific Maritime, Hudson Plains, Taiga Shield, Taiga Plains, Boreal, Taiga, and Arctic Cordillera ecozones each contain less than 10 species in need of conservation. The Northern and Southern Arctic ecozones do not contain any tree species. The ranking of ecozones changes slightly when the number of species in need of conservation is identified as a percentage of total tree species. The Prairie ecozone has the largest (86%), followed by the Atlantic Maritime (82%), Mixedwood Plains (77%), Boreal Shield (67%), Boreal Plains (61%), and Montane Cordillera (54%) ecozones. The remainder have 50% or less of their species in need of conservation.

Interestingly, the ecozones with the greatest number of tree species of concern also have the greatest number of COSEWIC-listed species (i.e., all flora and fauna) (Table 5). This suggests that broader reasons such as habitat loss and climate change may be responsible for species decline.

The three ecozones, Mixedwood Plains, Boreal Shield, and Atlantic Maritime, with the greatest number of species in need of conservation are the most southerly. The Prairie ecozone represents 5% of Canada's land area (Gauthier and Wiken 2003) and consists of predominantly native grassland. Only 16% of this ecozone is forested (Natural Resources Canada 2003), with 14 native tree species, predominantly deciduous, occurring along waterways or at higher elevations. In the eastern areas, *Populus tremuloides* dominates, whereas in the southwestern areas, open forests of *Pinus contorta* are present. This ecozone has been highly fragmented, with farmland accounting for 94% of the land base (Canadian Council on Ecological Areas 1996).

Mixedwood Plains

The Mixedwood Plains covers the Great Lakes – St. Lawrence River Valley, where approximately half of Canada's population resides (Ecological Stratification Working Group 1995). This ecozone was once rich with such species as *Pinus strobus*, *Tsuga canadensis*, *Betula alleghaniensis*, and *Pinus resinosa*. The large number of species in the Mixedwood Plains ecozone is influenced by the fact that it includes a small portion of the species-rich Carolinian forest, which reaches north into southern Ontario. The Carolinian forest has approximately 73 tree species, 30 of which occur in Canada only in this forest type (Waldron 2003). Many of the species are listed as being rare, or having an uncertain seed source, and there has been a general non-specific decline in the species, as well as a decline resulting from land-use pressures. Many of these species are at the northern fringe of their ranges, and their distribution in Canada is limited to southern Ontario, which is also the most densely populated area of the country. Much of the Carolinian forest occurs on sites and in habitats that are preferred for human use, and therefore, many of these species have suffered from forest harvest, habitat destruction, or habitat conversion.

Atlantic Maritime Ecozone

The Atlantic Maritime Ecozone, with the third highest percentage of forest cover (76%), is the region of Canada with the longest history of European settlement. Despite its rela-

Table 5. Tree species in need of conservation by ecozone

Ecozone	% land base[a]	Total number of species	Number in need of conservation based on survey results (rated at least RV 2)	% of total number of species in need of conservation based on survey results	Total number of species at risk as recommended by COSEWIC[b]
Mixedwood Plains	1.5	73	56	77	107
Atlantic Maritime	1.9	34	28	82	40
Boreal Shield	19.4	33	22	67	36
Boreal Plains	7.3	23	14	61	14
Montane Cordillera	5.1	24	13	54	33
Prairies	5.1	14	12	86	34
Pacific Maritime	2.2	20	6	30	38
Taiga Plains	6.3	10	5	50	10
Taiga Shield	13.6	10	5	50	21
Hudson Plains	3.8	11	5	45	6
Boreal Cordillera	4.9	12	3	25	6
Taiga Cordillera	2.9	9	2	22	3
Arctic Cordillera	2.5	2	1	50	5
Northern Arctic	14.8	0	0	0	10
Southern Arctic	8.4	0	0	0	0

[a]These values were obtained from Canadian Council on Ecological Areas 1996.
[b]These values include birds, mammals, fish, lichens, mosses, amphibians, Lepidoptera, plants, etc. that are recommended by COSEWIC to be listed as either endangered, threatened or of special concern (COSEWIC 2004).

tively small area (second smallest after the Mixedwood Plains Ecozone), it has the second highest tree species diversity, reflecting a high degree of ecological diversity, primarily because of geological and maritime influences. Much of the area has been exploited for wood products for more than three centuries, which has substantially changed the forest character (Loo and Ives 2003) and has probably contributed to the fact that the ecozone also has the second highest number of species requiring gene conservation. It is the second most densely populated region of Canada.

Northern ecozones

In contrast, the northern ecozones (Arctic Cordillera, Taiga Cordillera, Taiga Plains, Taiga Shield) do not face the same scale of development as the southern ecozones, but they are a continuation of the oil-rich Western Canada Sedimentary Basin, and as such, the potential for oil and gas exploration and development is great. Development of this nature may have a significant impact on the limited number of tree species in these areas, which are at the northern limits of their range (*Prunus pensylvanica*, *Prunus virginiana* var. *virginiana*, *Abies balsamea*, and *Abies lasiocarpa*).

In summary

Survey results indicate that 52% of native Canadian tree species need either *in situ* or *ex situ* conservation in at least one jurisdiction within their natural range, and 8% of tree species require more information before a designation can be made. The reasons for conservation concerns, based on the criteria listed by respondents, varied. The predominant reason was rarity, followed by uncertain viable seed source, preferred habitat of the species in high demand for other uses, substantial decrease in the range or frequency of a species, and regeneration prevented by harvesting practices.

Limitations and Problems Not Addressed in this Survey

The results of the survey provide a basis for identifying genetic conservation priorities for trees in Canada, but many questions remain. The geographic distribution of the species is an important consideration when setting priorities for conservation work and supporting research. For example, a warmer and drier climate in central Canada may increase the future value of genetic resources in the northern outlier populations of more southerly species. These populations are already adapted to northern photoperiods and are poised to take advantage of warming northern climates, given that suitable northern site conditions exist, so perhaps they should receive higher conservation priority than small populations in other parts of species' ranges. However, this dismisses the role of these populations in providing local ecological functions and services.

Many of the species identified in the survey are under pressure in only a portion of their range. The relative importance of expending resources and energy on populations of species that may be secure in other similar parts of their range must be questioned.

It may be difficult to justify conserving material from threatened outlying populations of species that are of limited economic, and unknown ecological, value, and about which we have little or no genetic knowledge. Would resources be better spent on studying population genetic parameters and adaptive significance of outlying populations of species known to have some importance? Should we attempt to quantify the ecological value of particular species that, at present, lack economic value, in order to set priorities?

An underlying issue is that for most species, nothing is known about the genetic diversity, population genetic structure, barriers to gene flow, or adaptive value of threatened populations. Populations occurring near the southern limit of species' ranges are likely to be under greatest pressure as a result of expected environmental changes as well as settlement and development pressures. Without specific genetic information, identifying high priority populations becomes a dangerous, speculative exercise.

Current Conservation Policies

In addressing the way to move forward, it is important to consider the existing federal policies and procedures for listing a species at risk (endangered, threatened, or of special concern) in Canada. Conservation policy has shifted from protecting the individual species to protecting habitats. Initially, in 1977, the provincial, territorial, and federal governments recognized the requirement for an official, national, science-based body responsible for the classification of Canadian species at risk. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent body of experts (i.e., federal, provincial, and territorial government, and non-governmental scientists), was formed to address this need, and is responsible for assessing and identifying species at risk (Environment Canada 2002a). An assessment for a species is submitted to and reviewed by COSEWIC, which then determines, based on science, whether the species is at risk. If the species is considered to be at risk, it is assigned to one of five categories: extinct, extirpated, endangered, threatened, or of special concern.

In 1988, the first national recovery program, "Recovery of Nationally Endangered Wildlife," was established to develop and implement strategies for the recovery of endangered species, and to prevent further deterioration in the condition of threatened species (Environment Canada 2003a). This program included COSEWIC-listed species. Both COSEWIC and the recovery program continue to function, and have been incorporated into the Government of Canada's "National Strategy for the Protection of Species at Risk." This strategy, which covers species and habitats at risk, contains three components: 1) the "National Accord for the Protection of Species at Risk," which recognizes that cooperation among the various political jurisdictions is essential for protecting species at risk (Environment Canada 1996); 2) the "Habitat Stewardship Program," a voluntary stewardship and incentive program (Environment Canada 2003b) and 3) the "Species At Risk Act," which identifies relevant regulations and orders-in-council (Environment Canada 2002b).

The "National Accord for the Protection of Species at Risk" was the first agreement that committed different levels of government to implementing their own legislation and programs for the protection of species at risk and their habitats. The Accord was signed by all provinces, territories, and the federal government in 1996 (Environment Canada 1996). The

Canadian Endangered Species Conservation Council was created under the Accord, with responsibility for the listing and recovery of species at risk. The Council's contribution to identifying species at risk was reported in *Wild Species 2000: the General Status of Species in Canada* (Canadian Endangered Species Conservation Council 2001). This list ranks over 1600 species, with classifications ranging from extirpated/extinct to not assessed or exotic. It was to be used to prioritize conservation efforts; however, it did not include any tree species, not even the tree species listed at that time by COSEWIC. The second component of the National Strategy is the "Habitat Stewardship Program," established in 2000 to contribute to the recovery and protection of species listed as endangered, threatened or of special concern (Environment Canada 2003b). This program allocates funding for species listed by COSEWIC as threatened and endangered and their habitats, and for species and habitats in which recovery plans, identified through such programs as the "Recovery of Nationally Endangered Wildlife," have been produced. This program is currently one of three federal programs that provide funding for work on species at risk.

The third component of the National Strategy deals with protection of these species under the "Species At Risk Act" (SARA). In June 2003, SARA was proclaimed, its purpose being to prevent wildlife species from becoming extinct and to provide for their recovery (Environment Canada 2002b). SARA protects species at risk and their habitats. However, it only applies to migratory birds, aquatic species, and species on federal lands. Most land in Canada is Crown or public land under provincial jurisdiction. The Act does include a "safety net" mechanism; where there is federal action if the provinces do not provide protection equivalent to that available under the Act. This "safety net" addresses the protection of remaining habitat and species at risk, and not the steps necessary for species recovery. In addition, use of the "safety net" is discretionary.

The SARA process starts with a species assessment conducted by COSEWIC, which produces a "Status Report" and gives the species a preliminary designation (e.g., extinct, endangered, threatened, species of concern). This is forwarded to the Canadian Endangered Species Conservation Council with the recommended designation. A consultation process occurs with the provinces or territories in which the species is found, and with Aboriginal peoples, stakeholders, and the public to determine whether the species should be added to the List of Wildlife Species at Risk (Schedule 1). The Minister of the Environment reviews the results of the consultation and makes recommendations to the Governor in Council (Governor General of Canada acting by and with the advice and consent of the Queen's Privy Council for Canada), who makes the final decision. Once a species has been listed under Schedule 1, a recovery strategy is produced, including an action plan, with timelines, identifying the measures necessary for species recovery.

It should be noted that many species received an official designation before SARA though COSEWIC, and recovery plans were initiated. A process is underway to reassess these species through the SARA procedure. In the interim, species that have not undergone reassessment are listed on either Schedule 2 (species previously listed by COSEWIC as endangered and threatened species) or Schedule 3 (species previously listed as being of special concern). Once the assessment has been made, these species will be considered for Schedule 1. There has been considerable confusion concerning this process. In addition, COSEWIC's role under SARA has also changed; it is now only advisory. The ultimate decision as to which species get legal protection lies with federal government.

As signatories of the Accord, all provinces and territories are required to establish complementary legislation and programs for the protection of species at risk. Ontario, Quebec, Manitoba, New Brunswick, Nova Scotia, and Newfoundland and Labrador have Endangered Species Acts, and the Yukon, British Columbia, Alberta, Saskatchewan, and Prince Edward Island have amended existing Wildlife Acts to include species at risk. Nunavut is in the process of modifying its existing Wildlife Act, but the Northwest Territories has no legislation. In addition, British Columbia's Forest and Range Practices Act, which took effect in 2004, provides some protection in areas where forest and range licensees operate (Government of British Columbia Ministry of Forests and Range 2004). It should be noted that there is substantial variation in the types of legislation and in its implementation. For example, not all provinces and territories have programs in place for the protection of species at risk (e.g., recovery plan and implementation of plan, effective enforcement for protection of species or habitat).

Canada's "National Strategy for the Protection of Species at Risk" illustrates the commitment of the federal, provincial, and territorial governments to conserve species at risk and their habitats. Although tree species at risk of extinction throughout their Canadian range are addressed by the National Strategy, specifically SARA, and species at risk in specific jurisdictions are addressed by some provinces, there is clearly a need for concerted and coordinated effort to conserve species and populations across jurisdictional boundaries before they receive official risk designations. "Silent extinctions" associated with loss of genetically distinct populations, or loss of locally adapted gene complexes, are not considered in federal or provincial legislation, yet may have devastating consequences for tree species faced with increasing environmental change. In addition, many of the reasons for designating a tree species as being of concern (i.e., preferred habitat of the species in demand for other uses, and harvesting practices prevent regeneration), and many of the drivers for these reasons (e.g., land-use change caused by extensive human development and activity) are not under the jurisdiction of the federal government. Thus, there are multi-jurisdictional challenges, involving federal, provincial, territorial, and municipal governments, which can result in disparate and fragmented conservation efforts.

Tree Species with Official Designation

Currently, all tree species previously listed by COSEWIC, except *Castanea dentata*, have been reassessed and placed on Schedule 1 with the same status previously assigned by COSEWIC (Table 6). *Castanea dentata*, which was listed as endangered by COSEWIC, was downgraded to threatened when listed under Schedule 2, whereas *Quercus shumardii*, which maintained its previous designation of special concern, is now listed under Schedule 3 (Table 6). Recovery plan activities are underway for seven of the nine species identified in

Table 6. Status of tree species under Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and Species at Risk Act (SARA)

Species	COSEWIC status	SARA status[a,b]	Recover Plan activities[a]
Castanea dentata (American chestnut)	Endangered	Threatened, Schedule 2[c]	yes
Celtis tenuifolia (Dwarf hackberry)	Threatened	Threatened, Schedule 1	yes
Fraxinus quadrangulata (Blue ash)	Special Concern	Special Concern, Schedule 1	no
Gymnocladus dioicus (Kentucky coffee-tree)	Threatened	Threatened, Schedule 1	yes
Juglans cinerea (Butternut)	Endangered	Endangered, Schedule 1	no
Magnolia acuminate (Cucumber tree)	Endangered	Endangered, Schedule 1	yes
Morus rubra (Red mulberry)	Endangered	Endangered, Schedule 1	yes
Ptelea trifoliate (Common hoptree)	Threatened	Threatened, Schedule 1	yes
Quercus garryana (Garry oak)	None	None	yes
Quercus shumardii (Shumard oak)	Special Concern	Special concern, Schedule 3[d]	no

[a]Based on Species at Risk Database (accessed August 2004) http: //www.speciesatrisk.gc.ca/search/default_e.cfm
[b]Schedule 1 is the official list of species that have been designated as extirpated, endangered, threatened and, of special concern.
[c]Schedule 2 — species that have been designated as endangered or threatened and have yet to be reassessed by COSEWIC using revised criteria. Once the reassessment is completed, the species is considered for inclusion in Schedule 1.
[d]Schedule 3 — species designated as of special concern that have not been reassessed by COSEWIC using the revised criteria. Once the reassessment is completed, the species is considered for inclusion in Schedule 1.

the survey. Only recovery activities for *Gymnocladus dioicus* and *Quercus garryana* are under ecosystem-specific recovery plans, the remainder of the species are covered under species-specific recovery plans.

Ten of the species identified as requiring either *in situ* or *ex situ* conservation (RV 2,3) have official designation (Table 6) by COSEWIC or SARA. All species listed, except *Quercus garryana*, are located in southern Ontario, but the range of butternut extends from Ontario through Quebec to New Brunswick.

The only jurisdictions that have tree species identified in their provincial species-at-risk list are British Columbia (*Pinus banksiana*, as of special concern) (British Columbia Ministry of the Environment 2005), Ontario (*Juglans cinerea* and *Morus rubra* as endangered; *Castanea dentata*, *Ptelea trifoliata*, *Celtis tenuifolia*, and *Gymnocladus dioicus* as threatened; and *Fraxinus quadrangulata*, *Quercus shumardii* as of special concern) (Ontario Ministry of Natural Resources' Species at Risk Section 2004), and Nova Scotia (*Thuja occidentalis* as threatened, *Fraxinus nigra* as of special concern) (Nova Scotia Department of Natural Resources 2005). All these species were identified as in need of conservation through the survey. In addition, two provinces, British Columbia and Ontario (southern Ontario), have gene conservation programs for tree species.

Conclusions and Recommendations

The survey provides valuable information concerning 1) where we possess scientific information for moving forward with either *in* or *ex situ* conservation efforts, and 2) where there is incomplete information. Concerning 1), where species-specific populations were identified as being at risk, *in situ* conservation may be required. Where this is not possible, it should be determined whether *ex situ* conservation is appropriate. For tree species that were identified as requiring *ex situ* conservation efforts, work can be prioritized by addressing first species threatened by exotic diseases and pests. This addresses an area where our knowledge tends to be more complete, and in certain cases, there is an immediate need for *ex situ* conservation. For example, trees that may be resistant to the disease or to pests may risk being cut because of aggressive sanitation measures (i.e., *Fagus grandifolia*, *Juglans cinerea*, and *Fraxinus* spp.).

In 2), addressing species that require additional information before a need for conservation can be determined, these species can be placed on a priority list for conducting species-specific research. The survey is a first attempt at identifying tree species of concern, but it can be used to prioritize genetic conservation efforts. In the long term, focused conservation efforts may reduce the number of tree species that are officially listed as endangered or threatened.

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