

Climate Resilient Planting for the Lake Simcoe Watershed

2024



Lake Simcoe Region
conservation authority



For more information, contact:

Lauren Moretto

Climate Change Specialist, Integrated Watershed Management

Lake Simcoe Region Conservation Authority

120 Bayview Parkway, Newmarket, Ontario

Canada, L3Y 3W3

Telephone: 905-895-1281

Email: info@LSRCA.on.ca

Web: www.LSRCA.on.ca

Recommended Citation:

Lake Simcoe Region Conservation Authority (LSRCA). (2024). Climate Resilient Planting for the Lake Simcoe Watershed. 68pp.

Acknowledgements

Thank you to Mystaya Touw, Julia Marko, Bill Thompson, and Kaitlyn Read for their technical input throughout the project and review of the final report. Additional thank you to Mystaya Touw for conducting the initial data collection and analysis of models and functional roles for each species on the planting list. We are also grateful to Cory Byron, Lori McLean, Christa Sharp, and Charlotte Grieve for their technical review and quality control review of the report. Thank you as well to Kathy Hillis for assistance with the accessible formatting of this report.

Executive Summary

Introduction

Human emissions of greenhouse gases are changing historical, long-standing climate patterns in the Lake Simcoe Watershed. These changes will alter the climate envelopes of plant and animal species as early as mid-century, bringing about a cascade of effects to other ecological aspects of species, such as altering future spatial distribution (ranges) and/or timing of biological processes (phenology) of species (McDermott & DeGroot, 2016; LSRCA 2020; Robertson et al., 2024). If species cannot keep up with the pace of climate change, this may result in asynchrony in plant and wildlife interactions (e.g. pollination, migration, and breeding), increased risks of pests and disease, local extinctions, and a loss of biodiversity from a region.

Lake Simcoe Region Conservation Authority (hereafter referred to as “the Conservation Authority”) is aware of the impact of shifting climate envelopes and phenological asynchrony on its restoration and forestry program operations. Acting on recommendations from Provincial plans and strategies and the Conservation Authority’s leading-edge strategies can help promote means to mitigate and adapt to these impacts of climate change. This includes maintaining the health of natural heritage systems and features and the function of low impact development. It can also complement efforts to improve climate resiliency in the watershed by promoting biodiversity, particularly for wildlife which have close relationships with plants. The Conservation Authority’s [Adapting Forestry Programs for Climate Change Report \(2018\)](#) is the first of its kind in the region and addresses these impacts for program operations and species of trees and shrubs. However, these impacts have not yet been examined for other vegetation types planted by the Conservation Authority.

Purpose, Intended Application, Target Audience, and Scope

The purpose of this project was to build on recommendations from the [Climate Change Adaptation Strategy](#) (2020) and the Conservation Authority’s [Adapting Forestry Programs for Climate Change Report](#) (2018) to achieve the following:

- 1) Assess the suitability of the Conservation Authority’s current plant and seed mix lists (hereafter referred to as “planting list”) for future climatic conditions (high emissions scenario, Representative Concentration Pathway 8.5) in the Lake Simcoe Watershed;
- 2) Investigate the impacts of phenological asynchrony between plants and wildlife, and how the species on the current/future planting list support wildlife, with particular focus on pollination and food-provisioning services for migrating birds; and
- 3) Suggest a list of climate-resilient species from Ontario’s Carolinian zone to supplement the planting list and improve the success of future restoration and forestry projects.



This report is intended for application within the Lake Simcoe Watershed and for a technical audience (i.e. municipal and conservation authority staff, consultants, and similar practitioners) to complement restoration and forest management planning and action that considers climate change. While analysis outside the watershed is out of scope, the information from this project may be used to inform restoration and forestry programming in neighbouring watersheds and should align with other regional climate change plans.

Methods

Climate Resiliency of Current Planting List

Following the methods in the Adapting Forestry Programs for Climate Change Report (LSRCA, 2018), we adopted a species distribution/climate envelope modelling approach to assess vulnerability of species on the planting list to mid-century climate (2041-2070), under a high emissions scenario (Representative Concentration Pathway 8.5; see [Section 4 for Methods](#) and [Section 5 for Results](#)). We consulted map outputs from two models on Natural Resource Canada's (NRC) Plant Hardiness Site (NRC, 2022) to evaluate the suitability of the Conservation Authority's current planting list for the projected future climate of the Lake Simcoe Watershed. We defined four categories to score the likelihood of persistence for each species on the planting list, namely: likely, unlikely, very unlikely, or extirpated. We also investigated the influence of habitat requirements (i.e. coefficients of conservatism and wetness) of the planting list species on their likelihood of persistence (Oldham, 2017). Finally, we assessed persistence scoring for insect-pollinated, flowering species and species that are a common food source for migrating birds (either from fruit or seed production or hosting insect prey) to identify future gaps in our planting list with respect to functional roles.

Supplementing the Current Planting List with Carolinian Species

To help promote biodiversity and build resiliency of the planting list to future climate, we explored supplementing the list with 46 plant species from Ontario's Carolinian zone (Ecoregion 7E; see [Section 6](#)), since climate envelopes and ranges of species from this zone either already extend into the watershed or may expand north into the watershed in the future (Nantel et al. 2014). We also strived to promote biodiversity among the additions, covering a variety of vegetation types, functional roles ([see Section 6.1.1](#)) and habitat requirements ([see Section 6.1.2](#)). We selected species that would likely persist in the watershed in mid-century, and at least unlikely persist in late-century under a high-emissions (Representative Concentration Pathway 8.5) scenario. This supplemented the diverse array of tree and shrub species already being planted by the Forestry and Restoration teams, including small amounts of Carolinian species, to promote the resiliency of restoration and afforestation projects.



Results and Management Implications

Below is a list of results from this analysis and associated recommendations for future planting:

1. Suitability of the Current Planting List for Future Climate

Results: While 73 per cent (94 out of 129) of species on the current planting list will persist (either likely or unlikely) in the watershed by mid-century, 27 per cent (35 out of 129) will very unlikely be found or will be extirpated from the watershed (Figure 5-1). Most of these species are trees (14) and shrubs (14).

Recommendations: Supplement the current planting list with a diverse list of 46 plant species from Ontario's Carolinian zone (Ecoregion 7E) that will likely persist in the watershed in mid-century, and at least unlikely persist in late-century under a high-emissions (Representative Concentration Pathway 8.5) scenario (Figure 6-2).

2. Building Resiliency among Flowering Species that are Pollinated by Insects

Results: Thirteen insect-pollinated, flowering species are very unlikely to persist or will be extirpated from the watershed (Figure 5-3). Ten of these species are shrubs that flower between April and July.

Recommendations: Supplement the current planting list with 24 insect-pollinated, flowering species from the Carolinian zone, including four shrubs that flower between April and July (Figure 6-3).

3. Building Resiliency among Species that Provide Food for Migrating Birds

Results: Twenty-two species that are moderately or highly important food sources for migrating birds are very unlikely to persist or will be extirpated from the watershed (Figure 5-5). Ten of these species are trees which are noted sources of insects and seeds, while another ten species are shrubs which are sources of insects, seeds, and/or fruits.

Recommendations: Supplement the current planting list with 18 species from the Carolinian zone that are moderately or highly important food sources for migrating birds, including five shrub species and five tree species which are moderate or highly important food sources of insects, fruits, and/or seeds (Figure 6-4).

4. Promoting Diversity in Habitat Requirements of Species

Results: The current planting list contains species with a variety of habitat requirements, which are thus appropriate for restoration projects in a variety of ecosystem types. Affinity to wetlands or habitat specificity does not predict the likelihood of persistence of species on the planting list (Figure 5-6 and Figure 5-7).

Recommendations: Supplement the current planting list with species from the Carolinian zone that are diverse in habitat requirements, including salt, shade, and urban tolerance (Figure 6-5 and Figure 6-6).



Future Sources of Stock and Assisted Migration

Sourcing of seed and seedlings (i.e. stock) and assisted migration are becoming points of discussion as Forestry and Restoration teams increasingly consider climate resiliency to ensure success of plantings. Ontario's Tree Seed Transfer Policy (MNRF, 2020) provides direction for sourcing and planting stock, integrating considerations of future climate. It will be increasingly adopted as the stock collected and stored under the previous seed zone system is transitioned to the current policy. In the interim, Restoration and Forestry teams should explore sourcing from a variety of Ontario seed zones, if possible.

This human-facilitated movement of species populations (i.e. assisted migration) is a contentious issue, providing several clear benefits but also posing risks that could be highly impactful (Ste-Marie et al. 2011). Nonetheless, we believe that assisted migration should be explored to support climate adaptation for plantings in the watershed because the risk of negative impacts is low. Namely, we propose sourcing seed from nearby populations and supplementing the list with Carolinian species that would likely naturally migrate into the watershed over time. It is hoped that this strategy will promote adaptation to a variety of future climatic conditions, however monitoring will be critical to ensure their success without negatively impacting the natural heritage system.

Conclusion and Next Steps

Climate change considerations and vulnerability assessments can help inform planning for restoration and forestry programs. We intended for this report to provide information to these programs about species selection and phenological considerations to promote a greater likelihood of success of future restoration and forestry projects (though, see Appendix C: Caveats and Considerations). We also recommended a variety of future directions to help guide related projects that could also inform climate resilient planting (Appendix D: Future Directions and Next Steps).

As climate awareness, planning, and action ramps up across and beyond the Lake Simcoe Watershed, it will become increasingly important to coordinate climate action with internal and external partners. This coordination can help promote regional standardization of climate action, generate synergistic outcomes, encourage efficient use of resources (e.g. leverage expertise and avoid unnecessary duplication of effort), and lead to comprehensive climate action planning. This report increases the breadth of considerations for restoration and afforestation at the Lake Simcoe Region Conservation Authority and beyond to help adapt project implementation with respect to a future climate.



Table of Contents

- 1.0 Introduction 1
 - 1.1 Background..... 1
 - 1.2 Purpose..... 3
 - 1.3 Intended Application, Target Audience, and Scope..... 4
- 2.0 Characteristics and Management of Natural Heritage Features in the Lake Simcoe Watershed..... 4
 - 2.1 Land Cover and Natural Heritage Features..... 4
 - 2.2 Current Programming for Restoration and Forest Management 5
- 3.0 Impacts of Climate Change on Plants and Wildlife in the Lake Simcoe Watershed 6
 - 3.1 Plant Health, Phenology, and Climate Envelopes 6
 - 3.2 Plant-Wildlife Interactions 8
 - 3.2.1 Phenological Asynchrony between Plants and Wildlife 8
 - 3.2.2 Increased Risks from Pests and Disease 8
- 4.0 Methods to Assess the Resilience of the Planting List to Future Climate 9
- 5.0 Results and Management Implications..... 11
 - 5.1 Suitability of the Current Planting List for Future Climate..... 11
 - 5.2 Persistence of Species with Functional Roles 12
 - 5.2.1 Insect-Pollinated, Flowering Plants 12
 - 5.2.2 Food Sources for Migrating Birds 14
 - 5.3 Persistence and Species Habitat Requirements 16
- 6.0 Building Resiliency to Future Climate in the Planting List 18
 - 6.1 Supplementing the Planting List with Carolinian Species Additions..... 18
 - 6.1.1 Ensuring Diversity of Functional Roles in Proposed Carolinian Zone Additions..... 20
 - 6.1.2 Ensuring Diversity of Habitat Requirements among Proposed Carolinian Zone Additions..... 22
 - 6.2 Future Sources of Seed and Seedlings 23
 - 6.2.1 Assisted Migration 24
- 7.0 Regional Coordination of Climate Change Planning 25
- 8.0 Conclusion 27
- 9.0 Glossary 28
- 10.0 References 30
- Appendix A: Lake Simcoe Region Conservation Authority’s Current Planting List..... 34
- Appendix B: Proposed Plant Species Additions from Ontario’s Carolinian Zone 55



Appendix C: Caveats and Considerations 62
 Appendix D: Future Directions and Next Steps 65

List of Figures

Figure 1-1. Climate change could cause phenological asynchrony in plant-wildlife interactions, such as pollination. 2
 Figure 2-1. Woodlands and wetlands make up most of the natural heritage features in the Lake Simcoe Watershed. 5
 Figure 3-1. Leafing out and flowering of plant species across the watershed may advance by up to 45 days by 2080 (LSRCA, 2020). 7
 Figure 3-2. Asynchrony between food availability and bird migration and breeding could impact bird survival. Climate change may also provide favourable conditions for spread of pests, like spongy moth. 9
 Figure 5-1. Likelihood of persistence in the Lake Simcoe Watershed by mid-century for species on the current planting list. 12
 Figure 5-2. Flowering time of trees, shrubs, and forbs on Lake Simcoe Region Conservation Authority’s current planting list. 13
 Figure 5-3. Persistence scoring of species on Lake Simcoe Region Conservation Authority’s current planting list arranged by flowering time. 14
 Figure 5-4. Number of species on Lake Simcoe Region Conservation Authority’s current planting list that provide food for migrating birds. 15
 Figure 5-5. Persistence scoring of species on Lake Simcoe Region Conservation Authority’s current planting list arranged by importance as a food source for migrating birds. 16
 Figure 5-6. Boxplots comparing mean (“x”) and ranges of coefficients of wetness among persistence score categories. 17
 Figure 5-7. Boxplots comparing mean (“x”) and ranges of coefficients of conservatism among persistence score categories. 18
 Figure 6-1. Spotted geranium (*Geranium maculatum*) is one of the 46 species from Ontario’s Carolinian zone recommended to supplement the current planting list. 19
 Figure 6-2. The number of species within each vegetation type that would be very unlikely to persist or would be extirpated from the current planting list (left), compared to suggested Carolinian zone additions (right). 20
 Figure 6-3. Flowering times of insect pollinated species from Ontario’s Carolinian zone. 21
 Figure 6-4. Number of Carolinian zone additions that provide food for migrating birds. 21
 Figure 6-5. Comparing mean (“x”) coefficients of wetness between Lake Simcoe Region Conservation Authority’s current planting list and Carolinian zone additions. 22



Figure 6-6. Comparing mean (“x”) coefficients of conservatism between Lake Simcoe Region Conservation Authority’s current planting list and Carolinian zone additions. 23



1.0 Introduction

1.1 Background

Human emissions of greenhouse gases are changing historical, long-standing climate patterns in the Lake Simcoe Watershed. Under a high-emissions climate scenario (Representative Concentration Pathway 8.5), mean annual temperatures are predicted to increase from the historical average of 6.8 degrees Celsius to 10.1 degrees Celsius by 2050 (LSRCA, 2020). Summers will be warmer and drier, and temperatures in the winter will average above freezing, resulting in less snow and more rain. Models also predict an increase in mean annual precipitation in the watershed by about 50 millimetres by mid-century. Precipitation events will be more intense, be longer in duration, and occur more frequently, especially in winter and spring.

Changes to climate patterns will alter the [climate envelopes](#) of plant and animal species as early as mid-century, bringing about a cascade of effects to other ecological aspects of species (McDermott & DeGroot, 2016; LSRCA 2020; Robertson et al., 2024). These changes may alter the spatial distribution, or [ranges](#), of some species. If the species can migrate to follow the climate envelope, this will potentially force those currently at the edge of their range out of the watershed in the future. However, [extirpation](#) is possible if species cannot keep up with the pace of climate change. Climatic changes in seasonal patterns may also affect [phenology](#), the timing of periodic biological processes (Mortsch et al., 2003). For example, warmer and wetter winters and springs may trigger biological processes to occur earlier, such as leaf out, flowering, or breeding. Depending on the magnitude of these shifts in phenology for each species, there may be asynchrony in plant and wildlife interactions, impacting processes like pollination, migration, and breeding (Figure 1-1).

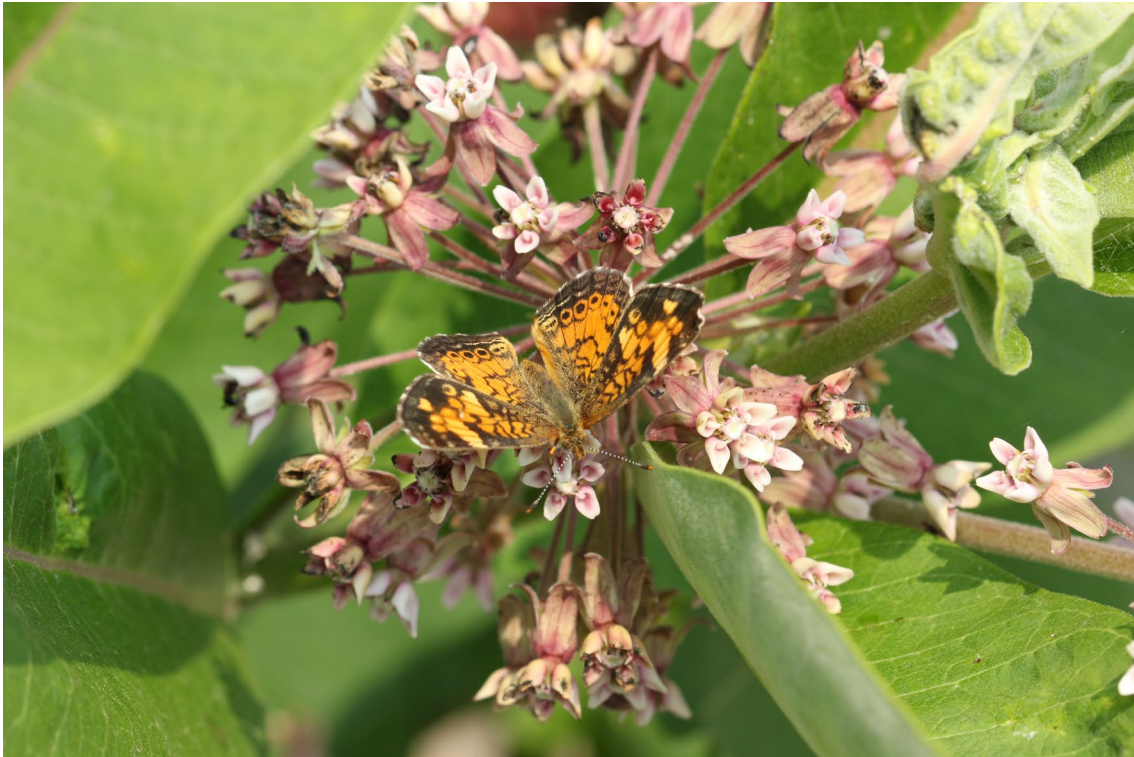


Figure 1-1. Climate change could cause phenological asynchrony in plant-wildlife interactions, such as pollination (photo credit, Chris Dunn).

Lake Simcoe Region Conservation Authority (hereafter referred to as “the Conservation Authority”) is aware of the impact of shifting climate envelopes and phenological asynchrony on its Restoration and Forestry program operations, and its Forestry program is already undertaking adaptive management outlined in the [Adapting Forestry Programs for Climate Change Report \(2018\)](#). This report is the first of its kind in the region and addresses these impacts for program operations and species of trees and shrubs, but these impacts have not yet been examined for other vegetation types planted by the Conservation Authority.

Effective planning and action are critical to ensure continued success of restoration and forestry projects. Strategically addressing shifting climate envelopes and phenological asynchrony for all species planted by these programs can help ensure adaptation to the watershed’s future climate. For example, this could impact the success of planting for afforestation and stormwater management, creation of [natural heritage features](#) for ecological offsetting, establishment of buffers around natural heritage features, or implementation of restoration plans required under policy. This may also improve the efficacy of engineered [low impact development](#) under a future climate scenario, reducing damage costs from storm impacts. Furthermore, we can complement efforts to improve the climate resilience of the watershed by

promoting biodiversity in our selection of plant species, particularly for wildlife which have close relationships with plants.

Several provincial plans (e.g. Greenbelt Plan, Lake Simcoe Protection Plan, etc.) recognize the importance of functioning low impact development features and healthy [natural heritage systems](#) and features, and call for the need to adapt ecosystem restoration and forest management for future climate scenarios. The Lake Simcoe Protection Plan Policy 7.11- Strategic Action states that risk assessments of climate change impacts and climate change adaptation planning are two strategic actions which can help increase resiliency of the watershed to climate change (MOE, 2009). To increase protection of aquatic and terrestrial natural heritage areas and connection to urban green spaces, Strategic Action 1.2 of the Lake Simcoe Climate Change Adaptation Strategy suggests “...planting a diverse mix of indigenous tree species, including those expected to be better adapted to climate change...” (MOECP, 2021). Provincial plans also prescribe the establishment of buffers composed of natural, self-sustaining vegetation to help build resiliency of natural heritage features.

Ensuring the health of low impact development features and natural heritage features and systems within the Lake Simcoe Watershed is embedded within the Conservation Authority’s core objectives, strategies, and operations. Directions One and Two of our [Strategic Plan](#) (2022-2024) make clear our objectives to “Champion Watershed Health and Climate Resilience” and to “Drive Evidence-based Decision Making” respectively. The [Natural Heritage System and Restoration Strategy](#) (2018) includes the suggestion to “integrate the natural heritage system into the Climate Change Adaptation and Mitigation Plans and the Adapting Forestry Programs for Climate Change Report to assist with identifying priority areas for migration corridors and afforestation that both sequester carbon and promote biodiversity resilience in the natural heritage system.” Lake Simcoe Region Conservation Authority’s [Climate Change Adaptation Strategy](#) (2020) recommends actions based on leading-edge science to help build resilience of natural systems across the watershed (LSRCA, 2020). The Conservation Authority is addressing these recommendations by developing and implementing program-specific climate action plans [e.g. [Adapting Forestry Programs for Climate Change Report \(2018\)](#)].

1.2 Purpose

In light of these calls to build resilience of natural heritage features and systems to climate change, the purpose of this project was to assess the resilience of Lake Simcoe Region Conservation Authority’s current plant and seed mix lists (hereafter referred to as “planting list”) to future climatic conditions in the Lake Simcoe Watershed. We also suggested supplementing the list with climate change-resilient species to improve the success, phenological alignment, and climate resilience of future restoration and forestry projects.



To achieve this purpose, we consulted Natural Resource Canada’s Plant Hardiness Site (NRC, 2022) to assess the likelihood of plants from the planting list persisting in the Lake Simcoe Watershed under future climate and flagged those which interact with pollinators and/or provide food for migrating birds. We also reviewed the scientific literature to understand the impacts of climate change on plant-wildlife interactions. We then suggested Carolinian species to supplement the list to help build climate resiliency into the list for future projects and noting that the ranges of Carolinian species will likely shift into the watershed by mid-century (Nantel et al., 2014). We consulted the New York City Parks planting list (NYC Parks, 2014) and Ontario’s Natural Heritage Information Centre’s list of [Ontario Carolinian zone](#) species (Oldham, 2017) to devise a list of potential Carolinian species additions.

1.3 Intended Application, Target Audience, and Scope

This report is intended for application within the Lake Simcoe Watershed and for a technical audience to complement restoration and forest management planning for climate change, such as that outlined in the Conservation Authority’s Adapting Forestry Programs for Climate Change Report (LSRCA, 2018). This includes, but is not limited to, municipal and conservation authority staff who plan and manage low impact development features (e.g. street trees, parks, naturalized stormwater ponds, permeable pavement, etc.) and [natural infrastructure](#) (e.g. natural heritage features and systems) across the Lake Simcoe Watershed. This also includes consultants (e.g. ecologists, landscape architects, etc.) who produce planting plans to fulfill planning policy and permit requirements. While analysis outside the watershed is out of scope, the results and information from this project can be used to generally inform restoration and forestry programming in neighbouring watersheds and should align with other regional climate change plans.

2.0 Characteristics and Management of Natural Heritage Features in the Lake Simcoe Watershed

2.1 Land Cover and Natural Heritage Features

The Lake Simcoe Watershed falls within Ecoregion 6E (Lake Simcoe-Rideau), which is characterized by its mild and moist temperate climate and gently undulating to rolling terrain (Crins et al., 2009). Land cover across the watershed consists primarily of natural heritage features (45 per cent) and rural land cover, including intensive agriculture (32 per cent), non-intensive agriculture (eight per cent), and developed agricultural land (three per cent). The remaining 12 per cent of the watershed is urban land cover. Woodlands and wetlands make up most of the natural heritage features of the watershed (Figure 2-1), occupying greater than 43,500 hectares and 54,600 hectares, respectively. Early successional features cover more than



27,000 hectares across the watershed, and a relatively small portion of the watershed (2,600 hectares) is occupied by native grasslands.



Figure 2-1. Woodlands and wetlands make up most of the natural heritage features in the Lake Simcoe Watershed (photo credit, Julia Marko).

2.2 Current Programming for Restoration and Forest Management

Lake Simcoe Region Conservation Authority has several departments and programs dedicated to protecting, enhancing, and restoring natural heritage features and systems and low impact development across the watershed. Our Restoration and Forestry programs directly target ecosystem restoration by working with partners including municipalities, First Nations, and community members/private landowners. Operations and projects implemented by these programs include tree planting, enhancement of wildlife habitat, stabilization of shorelines, stormwater management, and management of landholdings. Our Integrated Watershed Management and Planning and Development Services departments help to identify critical ecosystems for restoration and protection across the watershed. There are a suite of guidelines and reports from each of these programs to inform project planning and related considerations, including, but not limited to:

- [Subwatershed Plans](#) for each of the 12 subwatersheds in the Lake Simcoe Watershed;
- the [Natural Heritage System and Restoration Strategy](#);
- [Stormwater Management Guidelines](#) and the [Comprehensive Stormwater Management Master Plan](#); and
- [Regulation Implementation Guidelines](#).

See Lake Simcoe Region Conservation Authority's [Policies and Guidelines](#) for more information.



As climate change is currently impacting and continues to pose risks to the health of the watershed and the Conservation Authority's services, we need additional considerations and assessments to adapt program operations to future climate scenarios. Lake Simcoe Region Conservation Authority's Strategic Plan (2022-2024) and Climate Change Adaptation Strategy (2020) recognize the need to act and list recommendations based on leading-edge science to help build resilience of natural systems across the watershed. At the program level, the Adapting Forestry Programs for Climate Change Report (2018), recognizes the impacts of climate change on current operations and investigates how the Conservation Authority could incorporate climate change considerations into future planning for afforestation, natural area enhancement and restoration, and urban tree planting. The Conservation Authority is aiming to continue this progress in other sectors such as investigating climate change resilient natural channel design, implementing strategic stormwater controls and low impact development, and promoting agricultural best management practices.

This climate resilient planting project builds on recommendations from the Climate Change Adaptation Strategy (2020) and Lake Simcoe Region Conservation Authority's Adapting Forestry Programs for Climate Change Report (2018). It expands the analysis beyond trees and shrubs to include all species on our planting list, adds considerations of climate-caused asynchrony in plant-wildlife interactions, and suggests additions of Carolinian species to build climate resiliency. As such, we hope that this project will benefit programs with restoration operations by providing additional recommendations that support a comprehensive approach to climate resiliency. In particular, this project will provide the following:

- 1) information about the response of Lake Simcoe Region Conservation Authority's current/future planting list to future climate conditions;
- 2) information about how the species on the current/future planting list support wildlife, with particular focus on pollination and food-provisioning services; and
- 3) recommended species to consider planting in the future, including information about urban and salt tolerance (sourced from NYC Parks, 2014).

3.0 Impacts of Climate Change on Plants and Wildlife in the Lake Simcoe Watershed

3.1 Plant Health, Phenology, and Climate Envelopes

Climate change will continue to alter seasonal growing conditions for plants across the Lake Simcoe Watershed. In general, plants will face a warmer future, with mean annual temperatures in the watershed predicted to increase by 3.3 degrees Celsius by mid-century under a high emissions scenario (Representative Concentration Pathway 8.5; LSRCA 2020).

Winter and spring will become milder, accompanying an increase in mean annual precipitation by more than 50 millimetres. Although these conditions will extend the growing season and elevated carbon dioxide concentrations may accelerate plant growth, summers are predicted to become increasingly hot and dry by mid-century. It is predicted that there will be about 30 days with mean temperatures above 30 degrees Celsius by 2050, a five-fold increase over the baseline (1981-2010; LSRCA 2020).

Changes to seasonal growing conditions will shift the phenology and climate envelopes of plant species, introducing new risks and potentially shifting the distribution of species within the watershed. Warmer winters and springs may advance the onset of leaf out and flowering by up to 45 days in the watershed by 2080 (LSRCA, 2020; Figure 3-1), with notable advances among temperate species like tamarack (*Larix laricina*), starflower (*Trientalis borealis*), white trillium (*Trillium grandiflorum*), and trailing arbutus (*Epigaea repens*) (Gonsamo et al., 2013). However, earlier leaf out and flowering could impact the growth and reproductive success of plants. This could potentially increase susceptibility to damage from frost, asynchrony with moisture from snow melt, and may halt germination in some species if a particular temperature threshold is exceeded. At the same time, due to changes to climate envelopes, plant species that currently occur within the watershed at the southern end of their overall geographic range will unlikely be found in the watershed in the future. For example, future hot and dry summers may reduce the prevalence of drought intolerant species and species that favour more cool or moist conditions, such as variegated pond-lily (*Nuphar variegata*) and speckled alder (*Alnus incana*).



Figure 3-1. Leafing out and flowering of plant species across the watershed may advance by up to 45 days by 2080 (LSRCA, 2020) (photo credit, Julia Marko).



3.2 Plant-Wildlife Interactions

3.2.1 Phenological Asynchrony between Plants and Wildlife

Changes to the phenology and climate envelopes of plant species may cause a mismatch in plant-wildlife interactions, impacting the [fitness](#) of organisms that depend on these interactions (LSRCA, 2020). Asynchrony between the timing of flowering and emergence of or visitation by pollinators could reduce both the reproductive success of plants (i.e. lower fruit and seed yields) and food availability for pollinators (Fitchett et al., 2015). If insect species adapt to these shifts by aligning their lifecycles with earlier leaf out and flowering, this could impact food availability for herbivorous or insectivorous wildlife, like migrating birds (Figure 3-2).

Researchers are observing a notable lag in bird migration relative to leaf out and flowering (Robertson et al., 2024), which may reduce food availability during migration and nesting periods, and consequently the survival of birds. This may more greatly impact long-distance migrants, who have less flexible migration patterns and rely on non-climate cues (e.g. day length) more than short-distance migrants, and especially herbivorous species (McDermott & DeGroot, 2016; Robertson et al., 2024). Upon arrival to breeding grounds, breeding, nesting, and fledging may occur earlier (McDermott & DeGroot, 2016), be delayed (Boukherroub et al., 2024), or remain unchanged (Visser et al., 1998) depending on local conditions such as food availability and temperature. Nonetheless, climate change bears a risk of inadequate food availability for juveniles if the magnitude of asynchrony between plant and wildlife phenology increases (Baines et al., 1996; Pearce-Higgins, 2005).

3.2.2 Increased Risks from Pests and Disease

Depending on the species, climate change may provide more favourable conditions for the life cycles of insects and pathogens. As such, this may increase the frequency, intensity, and spatial extent of outbreaks (Hushaw, 2015), putting plant species across the Lake Simcoe Watershed at greater risk from these biological threats (LSRCA, 2020). For example, warmer winters may reduce dieback and expand the range of pests and disease that cannot tolerate freezing temperatures, like spongy moth (*Lymantria dispar*; Figure 3-2). Increased precipitation may also promote germination and propagation of pests and disease, including invasive plant species like garlic mustard (*Alliaria petiolata*) and European swallow-wort (*Cynanchum rossicum*). If these pests and disease lack natural biological controls in the watershed, there is risk of extensive spread and pronounced impacts to the health of ecosystems.



Figure 3-2. Asynchrony between food availability and bird migration and breeding could impact bird survival. Climate change may also provide favourable conditions for spread of pests, like spongy moth.

4.0 Methods to Assess the Resilience of the Planting List to Future Climate

While there are various approaches to assess future vulnerability of species to climate change, trait-based assessments and species distribution/climate envelope mapping are two of the most common means (Willis et al., 2015). Trait-based vulnerability assessments predict how a species will respond to climate change by considering how the biological characteristics of a species will affect its exposure, sensitivity, and adaptive capacity (Willis et al., 2015; CVC, 2023). Conversely, species distribution/climate envelope modelling integrates species occurrence data with parameters about climatic variables to spatially define where a species is and could be distributed in the future (Willis et al., 2015; NRC, 2022).

To align with the methods in the Adapting Forestry Programs for Climate Change Report (LSRCA, 2018), we consulted species distribution/climate envelope mapping on Natural Resource Canada's (NRC) Plant Hardiness Site (NRC, 2022) to evaluate the resilience of the Conservation Authority's current planting list to the future climate of the Lake Simcoe Watershed. Specifically, we evaluated suitability for mid-century climate (2041-2070) under a high-emissions climate scenario (Representative Concentration Pathway 8.5). We assessed outputs from mid-century models only as we had more confidence in their predictive power compared to late century models. We primarily consulted CanESM2 MaxEnt and ANUCLIM

models on the Plant Hardiness Site to assess the likelihood of persistence in the watershed. These models use different approaches to predict future species distributions:

- ANUCLIM models use minimum and maximum values of climate variables and existing occurrence data to define a species' climate envelope (Xu & Hutchinson, 2013). Core range and full range are mapped for each species. For more information see the [Technical Details](#) on the Plant Hardiness Site.
- MaxEnt models use machine-learning, existing occurrence data, and environmental variables to define the future distribution of a species based on probability of occurrence from 0 to 1 (Phillips et al., 2006). Ten bins are defined for mapping and a colour is assigned to each bin. For more information see the [Technical Details](#) on the Plant Hardiness Site.

To assess resilience, we defined four categories to qualitatively score the likelihood of persistence for each species on the planting list. The categorical scores were assigned based on averaging the outputs from both the ANUCLIM and MaxEnt models. The categories were as follows:

- Likely (green): this species is expected* to be found across most of the watershed.
- Unlikely (yellow): the species is not expected[†] to be found across most of the watershed. The spatial distribution of the species in the watershed may also be patchy.
- Very unlikely (orange): the species is not expected to be found within the watershed (if mapped within the watershed, is very sparse[‡]), but may be found in nearby watersheds.
- Extirpated (red): the species is not expected to be found within the watershed or in nearby watersheds.

* For ANUCLIM models, the Lake Simcoe Watershed is greater than 90 per cent covered by a “core” or “in range” status. For MaxEnt models, the probability of occurrence is 0.4 or greater if referring to MaxEnt models. The 0.4 probability threshold was defined as it aligned with evaluation criteria in the Adapting Forestry Programs for Climate Change Report (LSRCA, 2018) and this threshold is also considered ‘moderately suitable’ other similar studies that use Max Entropy modelling. Additionally, probability rarely exceeds 0.6 for species that we know exist in the watershed on both MaxEnt maps for 1971-2000 based on current climate data and models for mid-century climate.

† For ANUCLIM models, the Lake Simcoe Watershed is less than 90 but greater than 40 per cent covered by an “in range” status. For MaxEnt models, the probability of occurrence is less than 0.4 but greater than 0.1 if referring to MaxEnt models.

‡ For ANUCLIM models, the Lake Simcoe Watershed is less than 40 per cent covered by an “in range” status. For MaxEnt models, “very sparse” is associated with a probability of occurrence of less than 0.1.



We also explored the relationship between the persistence scoring and both [coefficients of conservatism](#) and [coefficients of wetness](#) for each species. We assessed these relationships to understand if habitat requirements of species on the Conservation Authority's planting list would help explain the likelihood of persistence in the future (Oldham, 2017). To achieve this, we created boxplots to visualize differences in mean coefficients of conservatism and coefficients of wetness between categories. We also conducted non-parametric Kruskal-Wallis tests since the data were not normally distributed to statistically examine the differences in median coefficients of conservatism and wetness among the categories.

Lastly, we assessed persistence scoring for 58 insect-pollinated, flowering species and 103 species that are a common food source for migrating birds (either from fruit or seed production or hosting insect prey) to identify future gaps in our planting list with respect to functional roles.

Note that while we did assess persistence of aquatic species on the Conservation Authority's planting list, these species are not included in other analyses, given our focus on terrestrial restoration in this report.

5.0 Results and Management Implications

5.1 Suitability of the Current Planting List for Future Climate

Overall, we found that Lake Simcoe Region Conservation Authority's current planting list is predicted to be fairly resilient to mid-century climatic conditions in the Lake Simcoe Watershed under a high emissions scenario (Representative Concentration Pathway 8.5) but could be supplemented to build additional resiliency (Figure 5-1). Sixty-four per cent of the species on the list (82 out of 129) will be likely present across most of the watershed between 2041 and 2070, while nine per cent of species (12 out of 129) will be unlikely found across the watershed. The remaining 27 per cent of species (35 out of 129) will very unlikely be found or extirpated from the watershed. These results align with those reported for tree and shrub species from the Adapting Forestry Programs for Climate Change Report (2018).

Tree and shrub species on the Conservation Authority's planting list made up most of the species that will be most impacted by future climate, as 14 out of 32 species of trees (44 per cent) and 14 out of 31 species of shrubs (45 per cent) will very unlikely be found or will be extirpated from the watershed in the future. Conversely, forbs and graminoids on the planting list made up most of the species that are likely to be present in the future (total of 43 species).

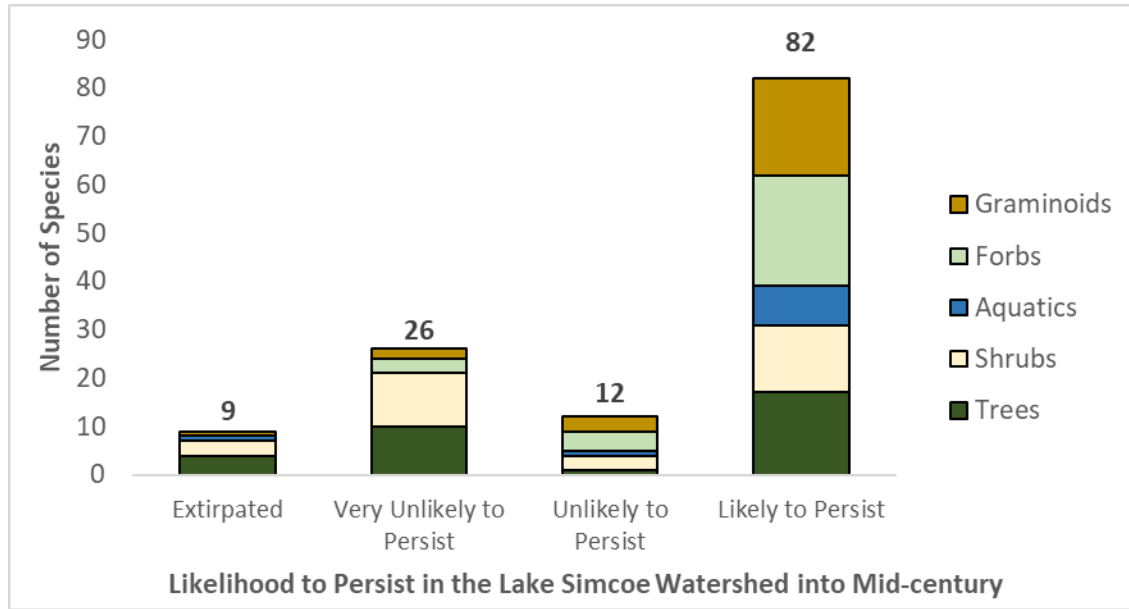


Figure 5-1. Likelihood of persistence in the Lake Simcoe Watershed by mid-century for species on the current planting list.

Management implications: While 73 per cent (94 out of 129) of species on the current planting list will persist (either likely or unlikely) in the watershed by mid-century under a high emissions scenario (Representative Concentration Pathway 8.5), 27 per cent (35 out of 129) will very unlikely be found or will be extirpated from the watershed (Figure 5-1; see Appendix A: Lake Simcoe Region Conservation Authority’s Current Planting List). Most of these species are trees (14) and shrubs (14). We recommend adding species to the list that will be resilient to the future climate of the watershed to support successful restoration and forestry projects ([see Section 6.1](#)).

5.2 Persistence of Species with Functional Roles

5.2.1 Insect-Pollinated, Flowering Plants

Of the 58 flowering species on the planting list that are insect-pollinated (NYC, 2014; CVC, 2015; NPCA, 2019), we found that most of the species (28) currently flower in June/July (Figure 5-2). Forbs make up most of the species that flower in June/July (16 out of 28). A notable amount of shrubs also flower in June/July (11 out of 28), but most shrubs (14) flower in April/May.

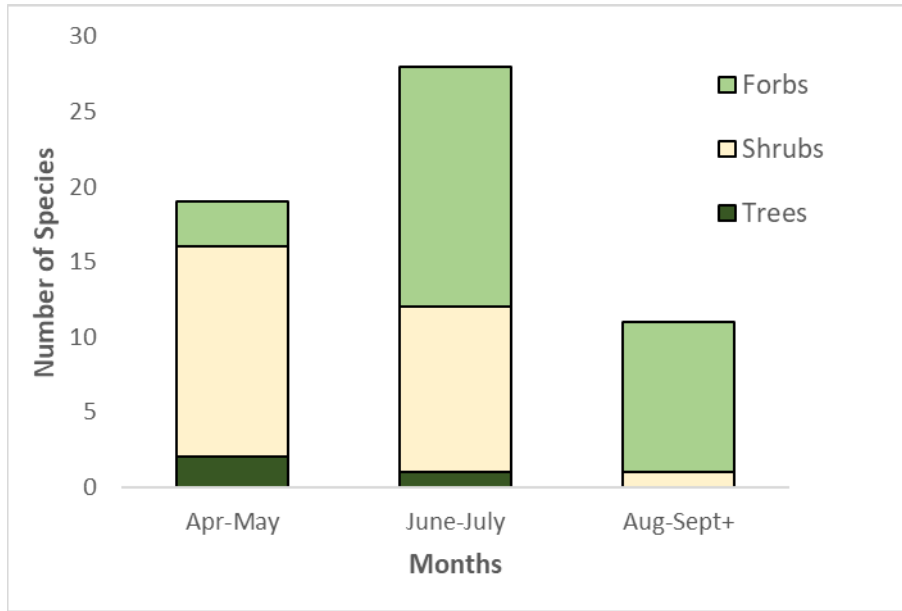


Figure 5-2. Flowering time of trees, shrubs, and forbs on Lake Simcoe Region Conservation Authority’s current planting list.

We found that most of the insect-pollinated species on the planting list are likely to persist in the watershed by mid-century (38 out of 58; Figure 5-3). Within each flowering time grouping, June/July contains the greatest proportion of species that are likely to persist (68 per cent of species that flower in June/July), while April/May contains the greatest proportion of species that are very unlikely to persist or will become extirpated (26 per cent of species that flower in April/May). Shrubs comprise most of the insect-pollinated, flowering species from our list that are very unlikely to persist or will become extirpated (10 out of 13 species). However, if future climate advances leaf out and budding for these species that are very unlikely to persist (LSRCA, 2020; see [Table A1](#)), the change in timing of blooming should be noted as this may shift the timing and increase the magnitude of impacts to pollinators.

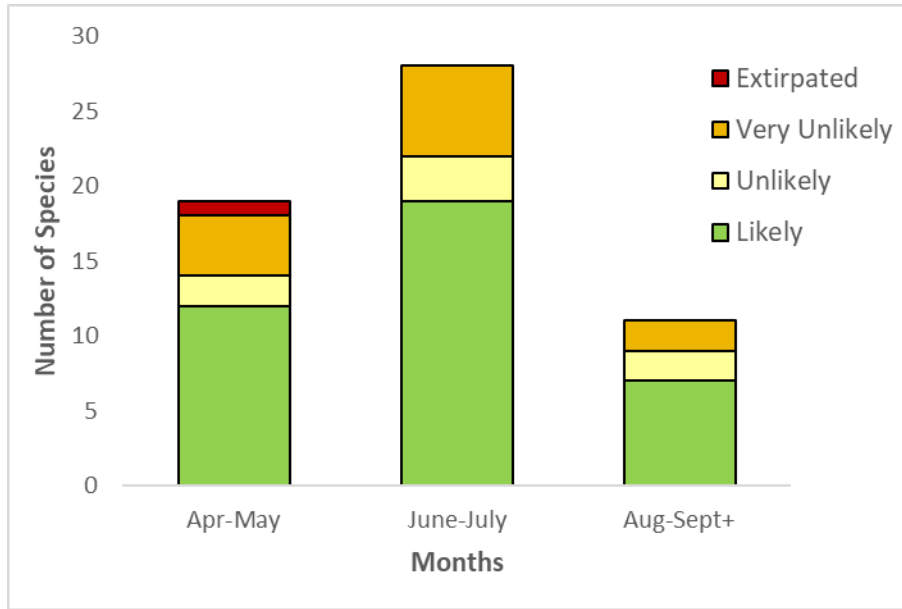


Figure 5-3. Persistence scoring of species on Lake Simcoe Region Conservation Authority’s current planting list arranged by flowering time.

Management implications: While most of the insect-pollinated flowering species on the planting list will persist (either likely or unlikely) in the watershed by mid-century, there are 13 species that are very unlikely to persist or will be extirpated from the watershed (Figure 5-3; see Appendix A: Lake Simcoe Region Conservation Authority’s Current Planting List). April/May and June/July contain a notable proportion of species that are very unlikely to persist or will be extirpated. Ten of these species are shrubs that flower between April and July. We recommend adding climate resilient species to the list that flower in April-July, and particularly shrubs, to fill these gaps ([see Section 6.1.1](#)). These results should be interpreted with awareness that future climate may advance leafing out and budding by over a month, shifting the timing and magnitude of impacts to pollinators (LSRCA, 2020).

5.2.2 Food Sources for Migrating Birds

While 103 species on the planting list provide food to migrating birds in some capacity, 71 species could be identified as being moderately or highly important food sources (Martin et al., 1951; Tallamy, 2007; NYC, 2014; CVC, 2015; Audubon Great Lakes, 2024). Most of these species that are moderate or highly important food sources on our planting list are shrubs (26 out of 71) or trees (24 out of 71; Figure 5-4).

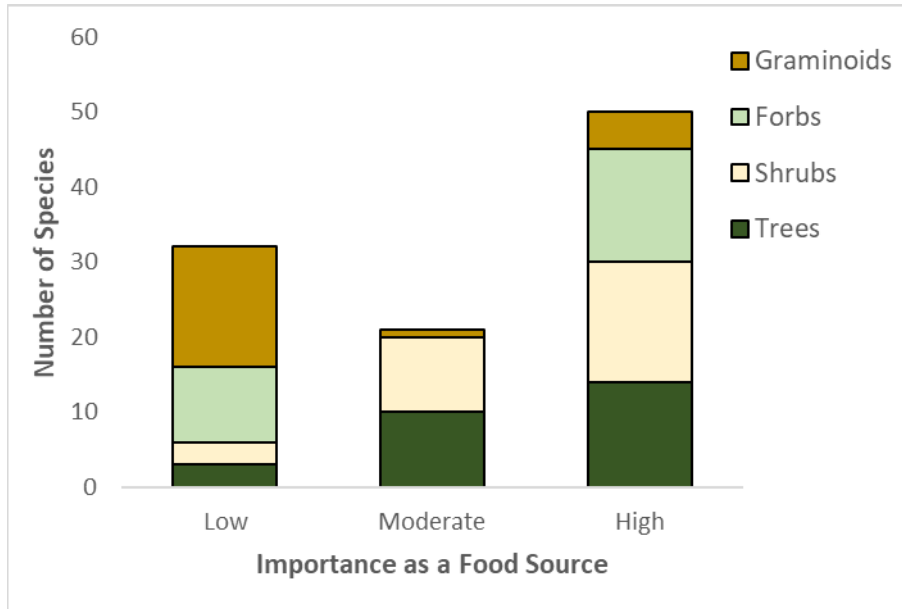


Figure 5-4. Number of species on Lake Simcoe Region Conservation Authority’s current planting list that provide food for migrating birds.

Although we found that most (64) of the 103 species that provide food to migrating birds will likely persist in the watershed by mid-century, 31 per cent of the moderately or highly important food source species (22 out of 71) are very unlikely to be found or will be extirpated from the watershed in the future (Figure 5-5). This includes ten shrub species and ten tree species. Five of the shrub species are noted sources of insects and fruits for migrating birds and three are sources of insects and seeds, while all of the tree species are noted sources of insects and seeds (Martin et al., 1951; Tallamy, 2007; NYC, 2014; CVC, 2015; Audubon Great Lakes, 2024). As with the results of the persistence analysis for insect-pollinated species, if future climate advances the timing of food provisioning services (e.g. fruit production, hosting larvae) for these species that are very unlikely to persist or will be extirpated (LSRCA, 2020; see [Table A1](#)), the change in timing should be noted as this may shift the timing and magnitude of impacts to migrating birds.

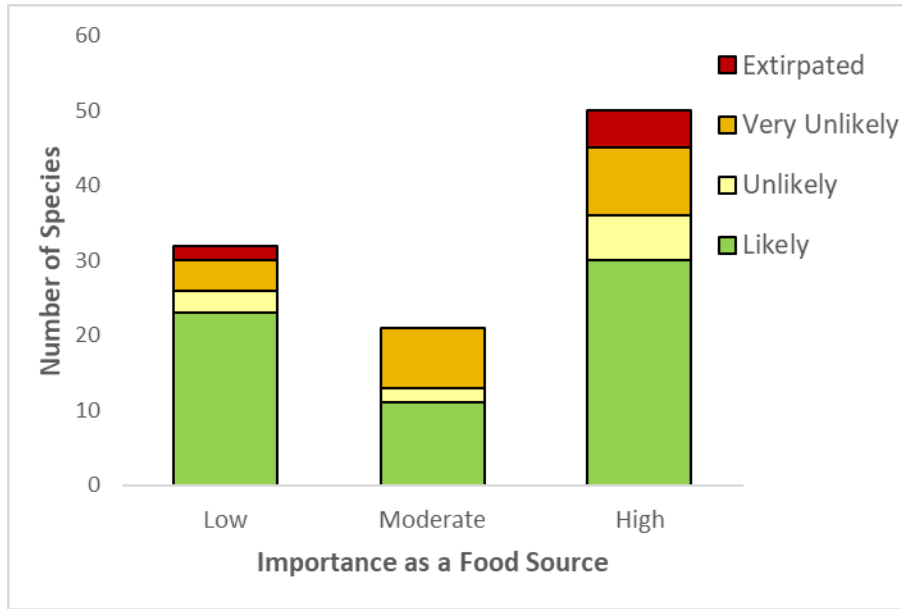


Figure 5-5. Persistence scoring of species on Lake Simcoe Region Conservation Authority’s current planting list arranged by importance as a food source for migrating birds.

Management implication: Thirty-one per cent of the 71 species identified as moderately or highly important food sources (22 out of 71) are very unlikely to be found or will be extirpated from the watershed in the future (Figure 5-5; see Appendix A: Lake Simcoe Region Conservation Authority’s Current Planting List). Ten of these species are trees which are noted sources of insects and seeds, while another ten species are shrubs which are sources of insects, seeds, and/or fruits. We recommend adding climate-resilient species that are highly-important food sources for migrating birds to fill these gaps, specifically shrubs that are sources of insects and fruits, and trees that are sources of insects and seeds ([see Section 6.1.1](#)). These results should be interpreted with awareness that future climate may advance leafing out and budding by over a month, shifting the timing of and magnitude of impacts to migrating birds (LSRCA, 2020).

5.3 Persistence and Species Habitat Requirements

Lake Simcoe Region Conservation Authority’s current planting list contains species appropriate for restoration projects in a variety of ecosystem types, indicated by the diversity of habitat requirements (i.e. coefficients of wetness and conservatism) of species on the planting list. [Coefficients of wetness](#) for species on the list range from the lowest (-5) scores for wetland species to the highest (5) scores for upland species, indicating that the list contains both species appropriate for wetland and upland restoration. However, the list contains a balance of wetland and upland species, with a mean coefficient of wetness of -0.64 (+/-3.5 S.D.).

Coefficients of conservatism on the planting list also range from the lowest (0) scores for habitat generalists to highest (10) scores for habitat specialists, with a mean score of 4.9 (+/-2.1 S.D.), suggesting that the list also contains a balance of both habitat generalists and specialists.

When we compared the coefficients of wetness and conservatism between persistence categories, we found that there were no trends related to likelihood of persistence. The results of Kruskal-Wallis tests suggested that there were no significant relationships between the persistence scoring and both coefficients of wetness (Figure 5-6; H statistic: 2.957, d.f. = 3, N = 127, p = 0.40) and coefficients of conservatism (Figure 5-7; H statistic: 4.871, d.f. = 3, N = 122, p = 0.18). In other words, this suggests that both the wetland and upland species on the planting list are equally resilient to a future climate.

To increase the utility of Lake Simcoe Region Conservation Authority’s planting list for a variety of applications, we scoped information from New York City Parks (NYC Parks, 2014) to highlight each species’ tolerance to salt, shade, and urban conditions (e.g. compaction, concrete, etc.; see Appendix A: Lake Simcoe Region Conservation Authority’s Current Planting List). While we did not explore the relationship between these qualities and future persistence in the watershed, they can inform decisions about planting for restoration.

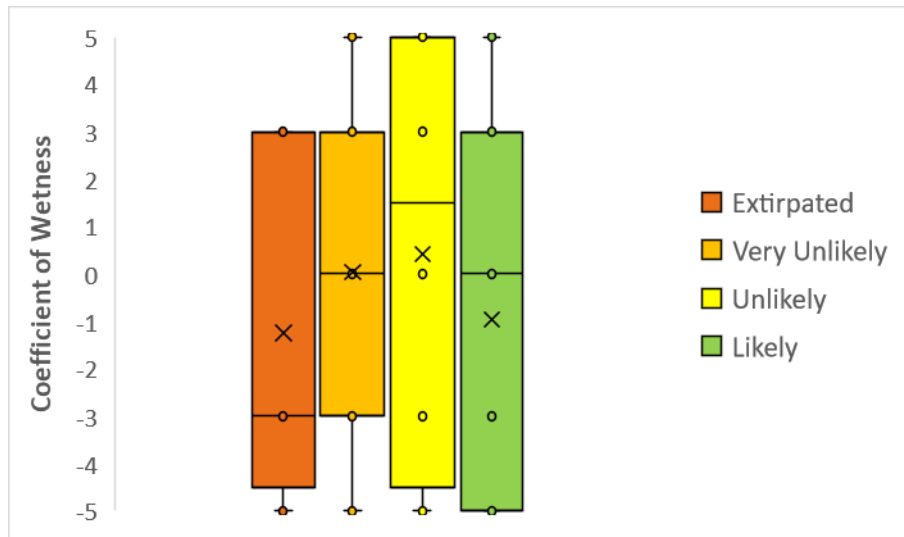


Figure 5-6. Boxplots comparing mean (“x”) and ranges of coefficients of wetness among persistence score categories.

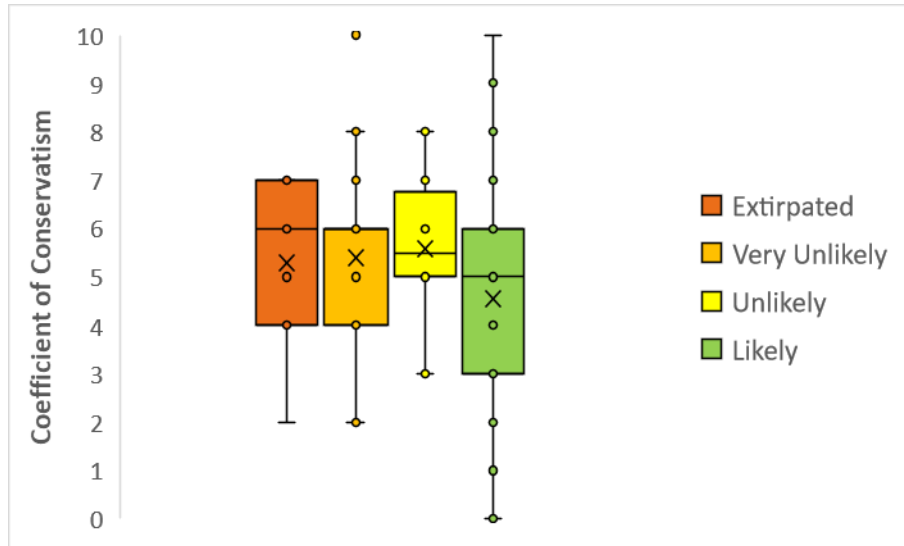


Figure 5-7. Boxplots comparing mean (“x”) and ranges of coefficients of conservatism among persistence score categories.

Management implication: Lake Simcoe Region Conservation Authority’s current planting list contains species appropriate for restoration projects in a variety of ecosystem types, indicated by the diversity of habitat requirements (i.e. coefficients of wetness and conservatism, salt tolerance, shade tolerance, and urban tolerance) of species on the planting list (see Appendix A: Lake Simcoe Region Conservation Authority’s Planting List). Although affinity to wetlands or habitat specificity does not predict the likelihood of persistence of species on the planting list (Figure 5-6 and Figure 5-7, respectively), we recommend building resiliency in the planting list by adding species that require a diversity of habitat requirements ([see Section 6.1.2](#)).

6.0 Building Resiliency to Future Climate in the Planting List

6.1 Supplementing the Planting List with Carolinian Species Additions

To help promote biodiversity and build resiliency of Lake Simcoe Region Conservation Authority’s planting list to future climate, we explored supplementing the list with 46 plant species from Ontario’s Carolinian zone (Ecoregion 7E; Figure 6-1). We selected species from the Carolinian zone as modelling suggests that climate envelopes and ranges of species from this zone either already extend into the watershed or may expand north into the watershed in the future (Nantel et al. 2014). We also strived to promote biodiversity among the additions, covering a variety of vegetation types, functional roles, and habitat requirements.



Figure 6-1. Spotted geranium (*Geranium maculatum*) is one of the 46 species from Ontario’s Carolinian zone recommended to supplement the current planting list (photo credit, Julia Marko).

To find appropriate species to supplement the Conservation Authority’s planting list, we first consulted a restoration plant list with Carolinian species from New York City (NYC) Parks (NYC Parks, 2014). This extensive list of 328 species provided a good foundation for exploring Carolinian species additions as it provided detailed recommendations for planting in a variety of habitats. We narrowed down the list by excluding any species recommended for planting in brackish water and/or coastal ecosystems and any species already on the Conservation Authority’s planting list. We then restricted the list to species currently native to Ontario by cross-referencing with the Natural Heritage Information Centre’s Ontario Carolinian zone list (Oldham, 2017).

To ensure additional climate resiliency, we evaluated climate MaxEnt CanESM2 climate models under a high emissions scenario (Representative Concentration Pathway 8.5) to filter out any species that would fare poorly in mid- and/or late-century climate conditions of the Lake Simcoe Watershed. Specifically, any species less than likely to persist by mid-century and less than unlikely to persist by late-century were removed from the list.

This resulted in forty-six species as suggested supplements to the current planting list after we applied all filter criteria. The proposed Carolinian additions included six tree species, six shrubs, 21 forbs, 11 graminoids, and two woody vines (Appendix B: Proposed Plant Species Additions from Ontario’s Carolinian Zone). This biodiverse list of additions complemented the existing list and addressed gaps in vegetation types that would be very unlikely to persist or extirpated

from the watershed by mid-century (Figure 6-2). We also note that Lake Simcoe Region Conservation Authority’s Forestry and Restoration teams had been applying the recommendations from the [Adapting Forestry Programs for Climate Change Report \(2018\)](#) and as such, had already been planting a diverse array of tree and shrub species, though in small amounts and mostly potted plants. This includes Carolinian species like tulip tree (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*), swamp white oak (*Quercus bicolor*), and American witch-hazel (*Hamamelis virginiana*). Therefore, in finding Carolinian species to supplement the current planting list, we could only identify six new tree and shrub species from Ontario’s Carolinian zone that met our criteria to suggest for climate resilient planting.

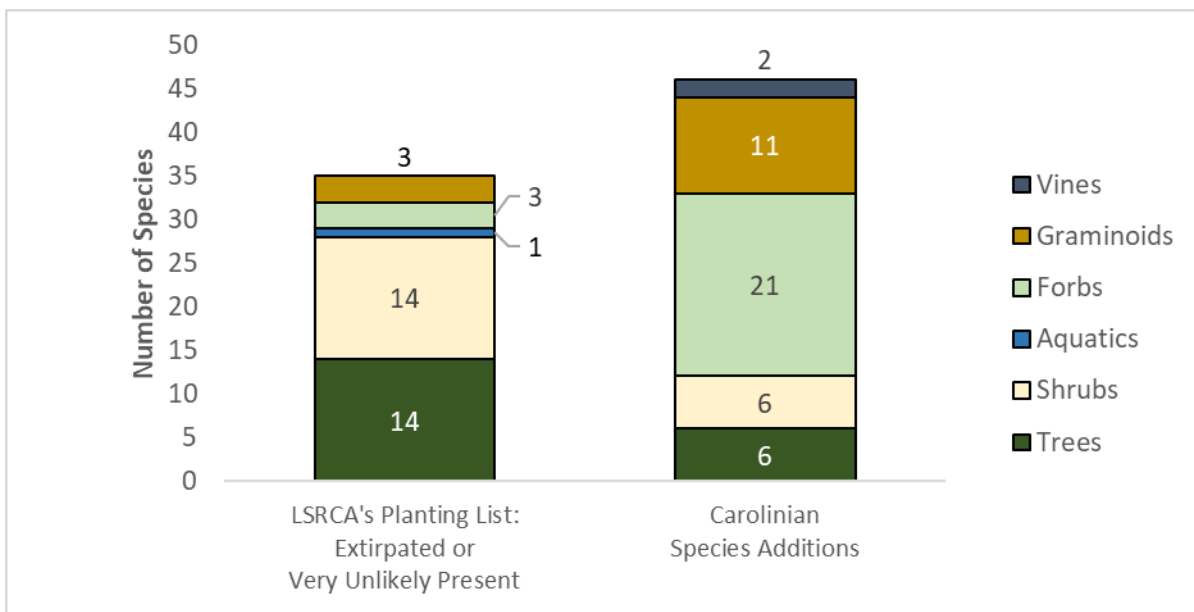


Figure 6-2. The number of species within each vegetation type that would be very unlikely to persist or would be extirpated from the current planting list (left), compared to suggested Carolinian zone additions (right).

6.1.1 Ensuring Diversity of Functional Roles in Proposed Carolinian Zone Additions

The proposed Carolinian zone additions also fill gaps in functional roles of species on Lake Simcoe Region Conservation Authority’s list that will likely not be found in the watershed by mid-century (Figure 6-3). Twenty-four of the 46 Carolinian zone additions are insect pollinated, flowering species. Seventeen of the 24 species flower in either April/May or in August and into the fall (NYC, 2014; CVC, 2015; NPCA, 2019), providing a good balance to the list which mostly contains species that flower in June/July. We are also proposing to add four shrubs that flower in April-July to offset species from the current list that flower during this time but are very unlikely to persist by mid-century.

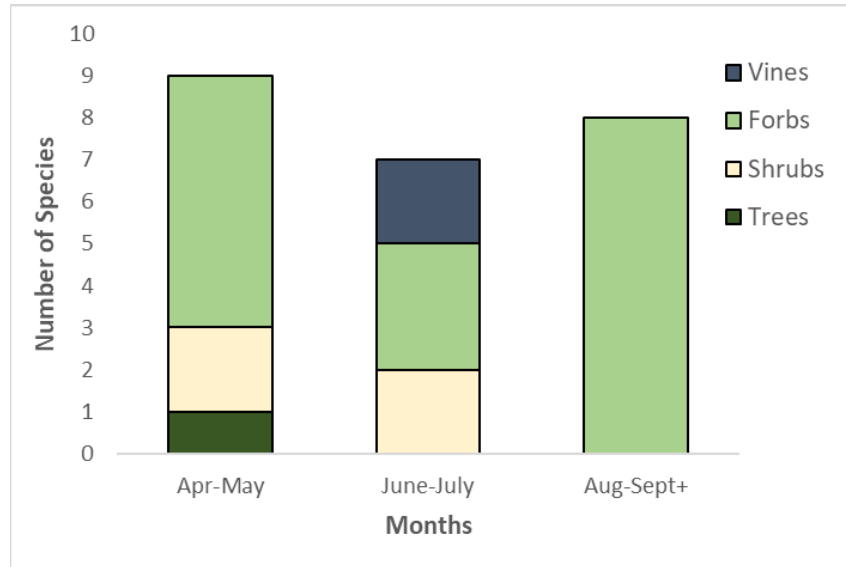


Figure 6-3. Flowering times of insect pollinated species from Ontario’s Carolinian zone.

Thirty-seven of the 46 proposed Carolinian zone additions provide a food source in some capacity to migrating birds, complementing the food-provisioning roles provided by species in the current planting list (Figure 6-4). Eighteen of these species are moderately to highly important food sources for birds (Martin et al., 1951; Tallamy, 2007; NYC, 2014; CVC, 2015; Audubon Great Lakes, 2024), adding to the 71 species on the existing list. This includes five shrub species and five tree species which are moderate or highly important food sources of insects, fruits, and/or seeds, which will help offset losses of food provisioning-services from the 10 shrub and 10 tree species on the current list that may not persist in the watershed by mid-century.

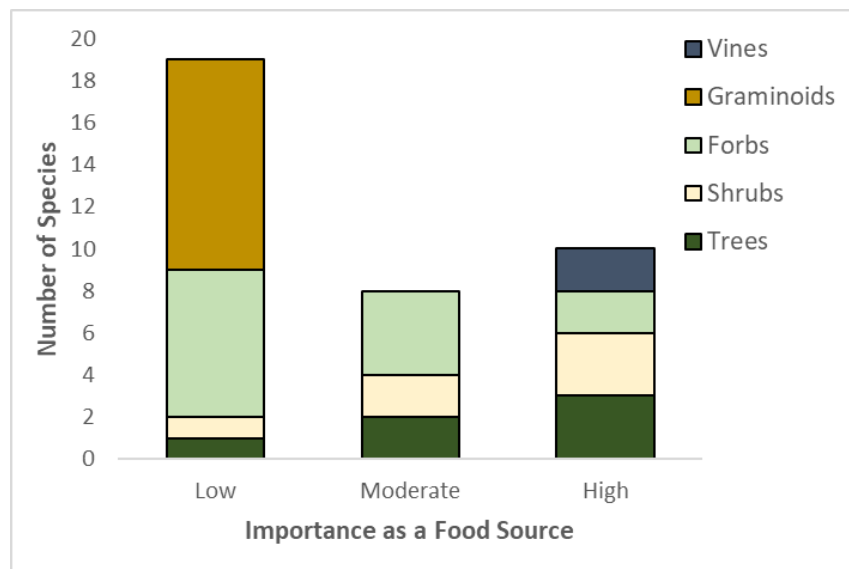


Figure 6-4. Number of Carolinian zone additions that provide food for migrating birds.

6.1.2 Ensuring Diversity of Habitat Requirements among Proposed Carolinian Zone Additions

The habitat requirements of the proposed Carolinian zone additions complement the habitat requirements of species on the current planting list, promoting additional resiliency by increasing biodiversity (see Appendix B: Proposed Plant Species Additions from Ontario’s Carolinian Zone). Compared to the range of coefficients of wetness and conservatism on the current planting list, the list of Carolinian zone additions contains on average more upland species (Figure 6-5; mean coefficient of wetness is 1.3 +/- 3.6 S.D.) and contains more habitat specialists (Figure 6-6; mean coefficient of conservatism is 6.5 +/- 2.2 S.D.). Having more upland species might be beneficial since we are expecting drier summer conditions in the watershed by mid-century. Proposed Carolinian zone additions were also diverse in salt, shade, and urban tolerance (NYC, 2014).

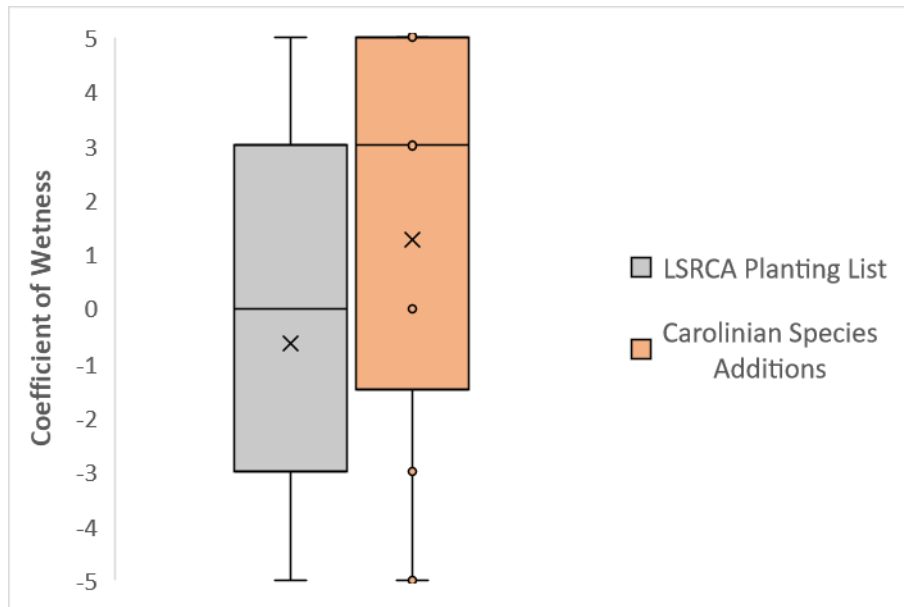


Figure 6-5. Comparing mean (“x”) coefficients of wetness between Lake Simcoe Region Conservation Authority’s current planting list and Carolinian zone additions.

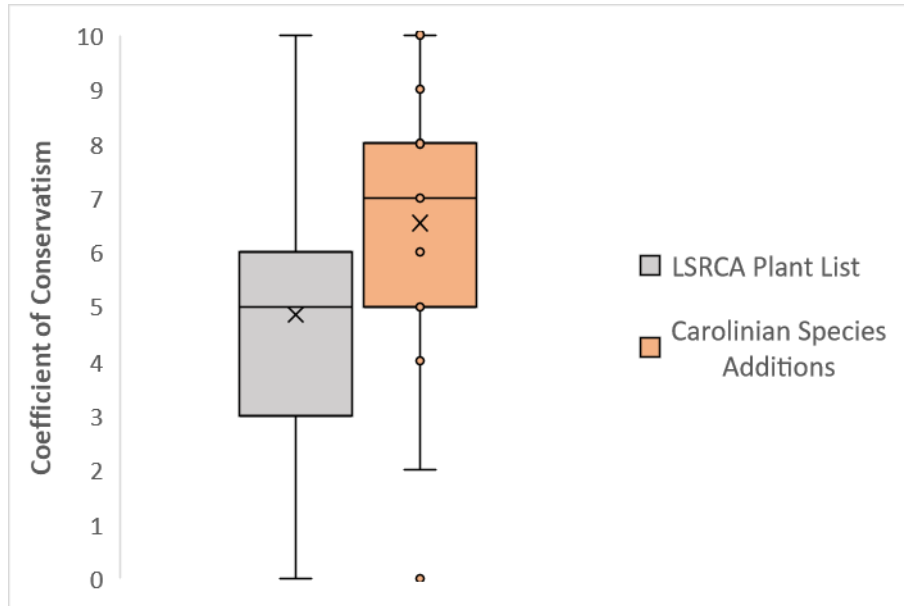


Figure 6-6. Comparing mean (“x”) coefficients of conservatism between Lake Simcoe Region Conservation Authority’s current planting list and Carolinian zone additions.

6.2 Future Sources of Seed and Seedlings

Ontario’s Tree Seed Transfer Policy (MNRF, 2020) provides direction for sourcing and planting seed and seedlings (i.e. stock) of trees and shrubs, integrating considerations of future climate. This new policy uses Ontario’s [ecodistricts](#) to delineate stock collection and deployment regions (i.e. [seed transfer areas](#)) to promote locally-adapted planting and retention of genetic diversity across the province. It will override the previous [seed zone](#) system (MNR, 2010), which designated 38 climatically-based seed zones for sourcing stock in Ontario.

Strategic planning for sourcing stock that integrates climate change considerations is necessary to build resiliency for future planting. As climate envelopes shift, locally-adapted plantings could become maladapted to local conditions and more susceptible to pests and disease in the future (O’Neil et al., 2017). Ontario’s Tree Seed Transfer Policy (MNRF, 2020) advocates for a climate-based approach which identifies where stock can be sourced or planted in light of a low emissions climate scenario (Representative Concentration Pathway 2.6). This approach minimizes risk of maladaptation while considering near future climate change (LSRCA, 2018; MNRF, 2020). Under this policy, a climate similarity analysis is applied which considers both historical (1961-1990) and near future (2011-2040) mean annual temperature, growing season length, and minimum temperature of the coldest month across ecodistricts and seed zones to define permissible regions for sourcing and planting stock (see “Climate similarity analysis” in MNRF, 2020 for more details).



It will take time to transition the stock that was collected and stored under the previous seed zone system to that of the current seed transfer policy (Cory Byron, 2024, pers. comm.). As such, the former seed zone system is largely still being applied by several nursery suppliers. In the interim, restoration and forestry teams should explore sourcing from a variety of Ontario seed zones, if possible (recognizing other factors that influence where to source stock, such as proximity, funding, availability, maturity, and species). Sourcing from multiple seed zones can help promote genetic diversity and adaptability (LSRCA, 2018; MNRF, 2020). Under the previous seed zone system, it was predicted that a three-degree Celsius increase in temperature may equate to a shift in three seed zones south. However, sourcing from other surrounding seed zones may be advantageous against multiple other climate impacts (e.g. providing resilience to frost and adaptation to longer day length/light exposure; LSRCA, 2018). Closely monitoring the success of plantings sourced from different seed zones will be necessary to advise sourcing, planting, and restoration strategies in the future (LSRCA, 2018; MNRF, 2020).

Lake Simcoe Region Conservation Authority's Forestry and Greenspace Services Department is incorporating these considerations into their operations. The department aims to source tree and shrub stock from three different seed zones in southern Ontario (Cory Byron pers. comm., 2024). Noting that this sourcing is highly dependant on the available stock from nursery suppliers, their target is to source 50 per cent of stock from seed zone 34, 25 per cent from seed zone 32, and 25 per cent from seed zone 37. It is hoped that this strategy will promote adaptation to a variety of future climatic conditions.

6.2.1 Assisted Migration

In light of the rapid pace of climate change, [assisted migration](#) of species by humans is being considered to support species movement to future, suitable climate envelopes. This strategy encompasses both human-facilitated movement of populations within a species' existing range (assisted population migration) and outside of its range (assisted range expansion or assisted long-distance migration), where the distance of migration depends on conservation goals for the species (Ste-Marie et al., 2011; NRC, 2024).

Assisted migration is a contentious issue, providing several clear benefits but also posing risks that could be highly impactful. On the one hand, assisted migration may help bypass various roadblocks to natural migration, including land use change or habitat loss, or an inability of species to keep up with the pace of climate change (i.e. cannot adapt to changing climate conditions within a region). This would especially support species with low dispersal abilities or specific habitat requirements (Ste-Marie et al., 2011). However, top of mind is also the uncertainty about how an introduced species may respond to relocation. There is a risk of the introduced species becoming invasive when released from typical limiting factors in its native environment, introducing new pests or disease, or altering other dynamics of an existing



ecosystem (Ste-Marie et al., 2011). Integrated into these considerations are cultural and political values about the ethics of deliberate human management of natural systems. Nonetheless, the decision to proceed with assisted migration is becoming urgent given the accelerated pace of climate change. Both policy frameworks and advancements in scientific understanding can facilitate decision making and action (Ste-Marie et al., 2011; NRC, 2024).

We believe that assisted migration should be explored to support climate adaptation for restoration and forestry programs in the Lake Simcoe Watershed because the benefits of proceeding outweigh the risks for the suggested Carolinian zone additions. In line with the recommended Adaptation Strategy 7.1.3 from the [Adapting Forestry Programs for Climate Change Report \(2018\)](#), we proposed adding species that would likely naturally migrate into the watershed overtime. All climate envelope models that we referenced (NRC, 2022) suggested that the Carolinian additions are likely to be found in the Lake Simcoe Watershed by mid-century and potentially into late century. Furthermore, several of these species on the Carolinian list currently naturally exist in the watershed, including blue-beech (*Carpus caroliniana*), dutchman's breeches (*Dicentra cucullaria*), and rosy sedge (*Carex rosea*). Nonetheless, projects that choose to plant the suggested Carolinian zone additions should be closely monitored for signs of potential invasive behaviour or introduced pests (LSRCA, 2018). As mentioned in the previous section, having multiple different sources of seed/seedlings should also be considered to increase the likelihood of success through resiliency from genetic diversity.

7.0 Regional Coordination of Climate Change Planning

As climate awareness, planning, and action ramps up across and beyond the Lake Simcoe Watershed, it will become increasingly important to coordinate climate action with internal and external partners. This coordination can help promote regional standardization of climate action, generate synergistic outcomes, encourage efficient use of resources (e.g. leverage expertise and avoid unnecessary duplication of effort), and lead to comprehensive climate action planning. For instance, part of the intent of this project was to build on the Conservation Authority's Adapting Forestry Programs for Climate Change Report (LSRCA, 2018) by expanding our analysis of climate vulnerability beyond trees and shrubs to all species on the planting list and examining impacts to plant-wildlife interactions. As such, this report increases the breadth of considerations for restoration and afforestation at Lake Simcoe Region Conservation Authority to help adapt project implementation with respect to a future climate. The information in this report can also be integrated with recommendations from municipal climate action, natural heritage, and restoration planning within and beyond the watershed. For example, the results of this analysis can be used to inform climate resilient planting for:



- green street policies;
- urban forest management plans;
- protection, compensation, or enhancement of the natural heritage system through plan review (e.g. landscaping and restoration plans for buffers, ecological offsetting, permit requirements for restoring disturbed areas);
- low impact development as part of green development standards (e.g. rain gardens, bioswales, etc.); and
- recommendations for all other restoration projects funded or implemented by Lake Simcoe Region Conservation Authority.

Although this analysis is specific to the Lake Simcoe Watershed, comparing our methodology and results with those of other studies in nearby jurisdictions can also help identify additional climate threats, trends, or actions for consideration. For example, our work both complements and can be informed by climate change vulnerability assessments for tree species and comparable ecosystems conducted in the Region of Peel and the Credit River Watershed. The Region of Peel and partners (2021) conducted climate change vulnerability assessments of tree species within or south of their jurisdiction. As well, Sansom (2020) and Credit Valley Conservation (CVC, 2023) conducted trait-based climate assessments of trees, integrating scoring of non-climate-related traits like genetic variability, dependence on other species, and sensitivity to pests and disease. We conducted a high-level comparison of the climate vulnerability scoring for tree species from this analysis to that of the other studies. We found that, while some of the climate vulnerability scoring for tree species was comparable, a higher climate vulnerability risk score was assigned to over half of the tree species by the other studies. Although this could relate in part to regional differences among future climates and impacts on tree species, it does not discount the value for Lake Simcoe Region Conservation Authority to consider species characteristics in future climate vulnerability assessments as they likely impact a species' capacity for climate resiliency.

Credit Valley Conservation's integration of these results into mapped Ecological Land Classification (ELC) data is also a good next step to consider for Lake Simcoe Region Conservation Authority to help understand climate vulnerability at an ecosystem level across the Lake Simcoe Watershed. This perspective can help inform natural heritage system planning and considerations in the review of development proposals. It can also help staff identify ecosystems at greatest risk for prioritizing conservation initiatives and restoration/forestry project planning.

8.0 Conclusion

Climate change considerations and vulnerability assessments can help inform planning for restoration and forestry programs. We intended for this report to provide information to these programs about species selection and phenological considerations to promote a greater likelihood of success of future restoration and forestry projects (though, see Appendix C: Caveats and Considerations). We also recommended a variety of future directions to help guide related projects that could also inform climate resilient planting (Appendix D: Future Directions and Next Steps).

Building on recommendations from previous strategies (LSRCA, 2018; LSRCA, 2020), we assessed the likelihood of persistence of each species on Lake Simcoe Region Conservation Authority's planting list under future climate in the watershed modelled with a high-emissions scenario. We found that 73 per cent of species on the current list (94 out of 129) would persist in the watershed by mid-century. We also suggested supplementing the list with additions of species from Ontario's Carolinian zone, which may persist to late-century, to promote resiliency through biodiversity. Our research also suggested that plant-wildlife interactions and phenology may also be impacted by climate change. To address this, we suggested 46 Carolinian species to help fill gaps in functional roles related to pollination and food provision for migrating birds. Lastly, we investigated considerations for seed sourcing and assisted migration.

While strategic planning of restoration and forestry projects can help build local resiliency to climate change, this should be paired with adaptation planning of natural heritage systems across and beyond the watershed. Lake Simcoe Region Conservation Authority should continue to work with its partners to examine the future vulnerability of ecosystems across the watershed, while continuing to protect ecosystems, encouraging connectivity between natural heritage features, and working with municipalities to promote strategic growth of urban centres. Our work on climate adaptation has just begun, and as climate risks continue to pose new challenges for the health of ecosystems across the Lake Simcoe Watershed, strategic planning and action will be more important than ever to work towards a climate-resilient future.

9.0 Glossary

Assisted migration: where humans facilitate the movement of a species to a new, climatically suitable habitat to keep up with a species' changing climate envelope. This can include the movement of populations within a species' current range or extending a species' range, either to adjacent locations or further away (Ste-Marie et al. 2011).

Ecodistrict: an ecosystem boundary defined by differences in geology, geomorphology, patterns of relief, substrate, microclimate, and the successional trends of its dominant vegetation community (Crins et al. 2009).

Extirpation: local extinction of a species or population from a defined geographic region where it historically existed.

Ontario's Carolinian zone: the southernmost ecoregion in Ontario characterized by milder year-round temperatures and hardwood forests supporting species with a strong southern affinity, including tulip tree (*Lireodendron tulipifera*), sassafras (*Sassafras albidum*), Kentucky coffee-tree (*Gymnocladus dioica*), cucumber tree (*Magnolia acuminata*), black gum (*Nyssa sylvatica*), and pawpaw (*Asimina triloba*) (ECCC, 2014).

Climate adaptation: the means of adapting strategies, procedures, or assets to a future climate to mitigate potential damage or leverage opportunities.

Climate change: long-term changes to temperature, precipitation, and weather patterns caused by human-induced increases in greenhouse gas emissions into the atmosphere, impacting natural and artificial processes (IPCC, 2014).

Climate envelope: a predicted species' spatial distribution defined by using climatic parameters correlated with species occurrence data.

Coefficient of conservatism: a rank system from 0 to 10 based on a species' degree of fidelity to plant community characteristics. Generalist plant species are assigned low ranks (higher tolerance to disturbance), while habitat specialists are assigned high ranks (greater restriction to intact habitats) (Oldham et al., 1995).

Coefficient of wetness: a rank system from -5 to 5 based on a species' tendency to grow in wetlands. A Score of -5 indicates a wetland obligate (almost exclusively found in wetlands), while a value of 5 indicates an upland obligate (almost never grows in wetlands) (Oldham et al., 1995).

Fitness: the reproductive success of an organism used as a means to quantify an individual's adaptation to its environment.



Low impact development: green technologies, including enhanced assets (e.g. urban trees, green roofs, bioswales, naturalized stormwater ponds) and engineered assets (e.g. permeable pavement, infiltration trenches), that collectively provide society with a multitude of economic, environmental, health, and social benefits (GIO, 2021).

Natural heritage feature: a natural area with significant ecological value for use in land use planning, such as a wetland, woodland, significant wildlife habitat, valleyland, fish habitat, area of natural or scientific interest, and/or key natural corridor or linkage (OMNR, 1999).

Natural heritage system: a collection of natural heritage features across a landscape and the connections among them (OMNR, 1999).

Natural infrastructure: natural assets (e.g. wetlands, forests, parks, meadows) that collectively provide society with a multitude of economic, environmental, health, and social benefits (GIO, 2021).

Phenology: the periodic appearance of life cycle events. This includes bloom, bud, and leaf emergence of flora, and the timing of breeding, migration, and development of fauna (Mortsch et al., 2003).

Range: a species' predicted spatial distribution.

Seed transfer area: a region defined by an Ontario ecodistrict and/or a previous seed zone where seeds and seedlings sourced from a specific location can be planted (MNRF, 2020).

Seed zones: a jurisdictional system to manage seed and stock movement, regeneration, and planting. There are 38 seed zones across Ontario devised to promote genetic diversity across the province and to ensure effective, locally adapted planting and seed regeneration (MNR, 2010).

10.0 References

- Audubon Great Lakes. Plantings for fall migrants. Accessed on September, 2024.
<https://gl.audubon.org/birds/plantings-fall-migrants>
- Baines, D., Wilson, I. A., & Beeley G. (1996). Timing of breeding in black grouse *Tetrao tetrix* and capercaillie *Tetrao urogallus* and distribution of insect food for the chicks. *Ibis*, 138(2): 181-187.
- Boukherroub, S., Desrochers, A., & Tremblay, J. (2024). Nesting phenology of migratory songbirds in an eastern Canadian boreal forest, 1996–2020. *Avian Conservation and Ecology*, 19(1): art2.
- Credit Valley Conservation (CVC). (2015). Native plant list for migrating birds. 15pp.
- Credit Valley Conservation (CVC). (2023). Climate change vulnerability of treed habitats in the Credit River Watershed. 59pp.
- Crins, W. J., Gray, P. A., Uhlig, P. W. C., & Wester, M. C. (2009). The Ecosystems of Ontario, Part I: Ecozones and Ecoregions. Ontario Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR- 01, 71pp.
- Environment and Climate Change Canada (ECCC). (2014). Conserve Ontario's Carolinian Forests: preserve songbird species at risk, chapter 1. Sourced from:
<https://www.canada.ca/en/environment-climate-change/services/migratory-bird-conservation/publications/ontario-carolinian-forests-preserve-songbird/chapter-1.html>.
- Fitchett, J. M., Grab, S. W., & Thompson, D. I. (2015). Plant phenology and climate change: Progress in methodological approaches and application. *Progress in Physical Geography*, 39(4): 460-482.
- Gonsamo, A., Chen, J. M., & Wu, C. (2013). Citizen Science: Linking the recent rapid advances of plant flowering in Canada with climate variability. *Scientific Reports*, 3(1): 2239.
- Green Infrastructure Ontario (GIO). (2021). Green Infrastructure: Overview. Sourced from:
<https://greeninfrastructureontario.org/what-is-green-infrastructure/>.
- Hushaw, J. (2015) Forest pests and climate change. 13pp. Retrieved from
https://www.manomet.org/sites/default/files/publications_and_tools/Forest-Pests-and-Climate-Change_FullBulletin.pdf.

- Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151pp.
- Lake Simcoe Region Conservation Authority (LSRCA). (2018). *Adapting Forestry Programs for Climate Change*. 91pp.
- Lake Simcoe Region Conservation Authority (LSRCA). (2020). *Climate Change Adaptation Strategy for the Lake Simcoe Region Conservation Authority*. 258pp.
- Martin, A. C., Zim, H. S., & Nelson A. L. (1951). *American wildlife and plants: a guide to wildlife food habits*. Dover Publications, NY.
- McDermott, M. E., & DeGroot, L. W. (2016). Long-term climate impacts on breeding bird phenology in Pennsylvania, USA. *Global Change Biology*, 22(10): 3304–3319.
- Mortsch, L., Alden, M., & Scheraga, J. D. (2003). *Climate change and water quality in the Great Lakes Region: Risks, opportunities and responses. A Report Prepared for the Great Lakes Water Quality Board of the International Joint Commission*. 135pp.
- Nantel, P., Pellatt, M.G., Keenleyside, K., & Gray, P.A. (2014). *Biodiversity and Protected Areas; in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*, (ed.) F.J. Warren, & Lemmen, D.S.; Government of Canada, Ottawa, ON, 159-190pp.
- Natural Resources Canada (NRC). (2022). *Canada's Plant Hardiness Site*.
<http://planthardiness.gc.ca/>
- Natural Resources Canada (NRC). (2024). *Assisted migration*. <https://natural-resources.canada.ca/climate-change/climate-change-impacts-forests/adaptation/assisted-migration/13121>
- Niagara Peninsula Conservation Authority (NPCA). (2019). *A Guide to Celebrate Niagara Peninsula's Native Plants*. 96pp.
- New York City Parks (NYC Parks). (2014). *Native Species Planting Guide for New York City*, 2nd Edition. 309pp.
- Oldham, M. J., Bakowsky, W. D., & Sutherland, D. A. (1995). *Floristic Quality Assessment System for Southern Ontario*. Natural Heritage Information Centre, Ontario Ministry of Natural Resources. 69pp.

- Oldham, M. J. (2017). List of the Vascular Plants of Ontario's Carolinian Zone (Ecoregion 7E). Carolinian Canada and Ontario Ministry of Natural Resources and Forestry. Peterborough, ON. 132pp.
- O'Neill, G., Wang, T., Ukrainetz, N., Charleson, L., McAuley, L., Yanchuk, A., & Zedel, S. (2017). A Proposed Climate-based Seed Transfer System for British Columbia. Technical Report 099. Province of British Columbia.
- Ontario Ministry of the Environment (MOE). (2009). Lake Simcoe Protection Plan. Queen's Printer for Ontario. Toronto. 103pp.
- Ontario Ministry of the Environment, Conservation, and Parks (MOECP). (2021). Lake Simcoe Climate Change Adaptation Strategy. Accessed from: <https://www.ontario.ca/page/lake-simcoe-climate-change-adaptation-strategy>
- Ontario Ministry of Natural Resources (OMNR). (1999). Natural Heritage Reference Manual for Policy 2.3 of the Provincial Policy Statement. Ontario Ministry of Natural Resources. 127pp.
- Ontario Ministry of Natural Resources (MNR). (2010). Seed Zones of Ontario. Directive FOR 06 02 01. Ontario MNR, Forest Health and Silviculture Section.
- Ontario Ministry of Natural Resources and Forestry (MNRF). (2020). Ontario Tree Seed Transfer Policy. 51pp.
- Pearce-Higgins, J. W., Yalden, D. W., & Whittingham, M. J. (2005). Warmer springs advance the breeding phenology of golden plovers *Pluvialis apricaria* and their prey (Tipulidae). *Oecologia*, 143(3): 470-476.
- Phillips, S. J, Anderson, R. P., & Schapire R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, 190: 231-259.
- Region of Peel, Town of Caledon, City of Mississauga, City of Brampton, Credit Valley Conservation, Toronto and Region Conservation Authority. (2021). Potential street and park tree species for Peel in a climate change context. Peel Region Urban Forest Best Practice Guide 4, October 2021. 139 pp.
- Robertson, E. P., La Sorte, F. A., Mays, J. D., Taillie, P. J., Robinson, O. J., Ansley, R. J., O'Connell, T. J., Davis, C. A., & Loss, S. R. (2024). Decoupling of bird migration from the changing



phenology of spring green-up. *Proceedings of the National Academy of Sciences*, 121(12): e2308433121.

Sansom, M. (2020). Climate change vulnerability assessment of 55 tree and shrub species in the Greater Toronto Area. Final technical report submitted to Credit Valley Conservation. 49pp.

Ste-Marie, C., Nelson, E. A., Dabros, A., & Bonneau, M.-E. (2011). Assisted migration: Introduction to a multifaceted concept. *Forestry Chronicle*, 8(6):724–730.

Tallamy, D. W. (2007). *Bringing nature home: how you can sustain wildlife with native plants*. Timber Press, Portland.

Visser M. E, van Noordwijk, A. J., Tinbergen, J. M., & Lessells, C. M. (1998). Warmer springs lead to mistimed reproduction in great tits (*Parus major*). *Proceedings of the Royal Society of London B: Biological Sciences*, 265(1408): 1867-1870.

Willis, S. G., Foden, W., Baker, D. J., Belle, E., Burgess, N. D., Carr, J. A., Doswald, N., Garcia, R. A., Hartley, A., Hof, C., Newbold, T., Rahbek, C., Smith, R. J., Visconti, P., Young, B. E., & S. H. M., Butchart. (2015). Integrating climate change vulnerability assessments from species distribution models and trait-based approaches. *Biological Conservation*, 190: 167-178.

Xu, T., & Hutchinson, M. F. (2012). New developments and applications in the ANUCLIM spatial climatic and bioclimatic modelling package. *Environmental Modelling & Software*, 40: 267-279.

Appendix A: Lake Simcoe Region Conservation Authority’s Current Planting List

Table A1. Lake Simcoe Region Conservation Authority's current planting list, including (if available) flowering season for insect-pollinated species, type of insect pollinator, ranking of importance as a food source for migrating birds (Impt. as a Food Source for Migr. Birds), and type of food provided (Martin et al., 1951; Tallamy, 2007; NYC, 2014; CVC, 2015; Audubon Great Lakes, 2024). Details about salt and urban tolerance, if available, were sourced from NYC Parks (2014). Coefficient of Conservatism (Coeff. of Cons.) and Coefficient of Wetness (Coeff. of Wet.) were sourced from the Natural Heritage Information Centre (Oldham, 2017). Likelihood of persistence to mid-century is reported from Canada’s Plant Hardiness Site (NRC, 2022). Other abbreviations are as follows: “mod” = Moderate. “ROW” = Right of Way. Non-native, naturalized tree species are flagged with a *. Note that, while the Conservation Authority requires native species for planting plans, non-native but non-invasive, naturalized species have utility for afforestation and restoration under specific contexts and are being strategically planted by our Forestry and Restoration teams.

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
Trees											
tree	<i>Abies balsamea</i>	balsam fir			high	insects, seeds			5	-3	extirpated
tree	<i>Acer rubrum</i>	red maple			high	insects, seeds	no	Tolerates soil compaction, pollution, ozone and sulfur dioxide, performs well in ROW. Tolerant of shade.	4	0	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
tree	<i>Acer saccharinum</i>	silver maple			mod	insects, seeds	mod	Tolerates soil compaction, sensitive to ozone. Tolerant of partial shade.	5	-3	likely
tree	<i>Acer saccharum</i>	sugar maple			high	insects, seeds	no	Does not tolerate soil compaction, performs well in ROW. Tolerant of shade.	4	3	likely
tree	<i>Acer x freemanii</i>	hybrid soft maple							6	-5	very unlikely
tree	<i>Betula alleghaniensis</i>	yellow birch			high	insects, seeds	mod	Tolerant of urban conditions. Intolerant of shade.	6	0	very unlikely
tree*	<i>Betula nigra</i>	river birch					no	Resistant to soil compaction, prefers acidic soils, performs well in the right of way. Intolerant of shade.			likely
tree	<i>Betula papyrifera</i>	paper birch			high	insects, seeds			2	3	extirpated
tree	<i>Carya cordiformis</i>	bitternut hickory			mod	insects, seeds	no	Tolerant of concrete debris. Tolerant of shade.	6	0	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
tree	<i>Carya ovata</i>	shagbark hickory			low	insects, seeds	no	Intermediate tolerance of soil compaction. Moderately tolerant of shade.	6	3	likely
tree	<i>Celtis occidentalis</i>	common hackberry			mod	insects, seeds	yes	Tolerant of concrete debris; intolerant of soil compaction, performs well in the right of way. Tolerant of pollution. Moderately tolerant of shade.	8	0	likely
tree	<i>Gymnocladus dioica</i>	Kentucky coffee-tree							6	3	likely
tree	<i>Juniperus virginiana</i>	eastern red cedar			high	insects, seeds, fruits	mod	Intolerant of soil compaction; tolerant of concrete debris, performs well in the right of way. Intolerant of shade.	4	3	likely
tree*	<i>Larix decidua</i>	European larch								5	very unlikely
tree	<i>Larix laricina</i>	American larch/ tamarak			high	insects, seeds			7	-3	extirpated

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
tree	<i>Liriodendron tulipifera</i>	tulip tree			mod	insects	no	Intolerant of soil compaction, performs well in the right of way. Moderately tolerant of shade.	8	3	unlikely
tree*	<i>Picea abies</i>	Norway spruce								5	very unlikely
tree	<i>Picea glauca</i>	white spruce			high	insects, seeds			6	3	extirpated
tree	<i>Pinus resinosa</i>	red pine			mod	insects, seeds	no	Sensitive to soil compaction. Moderately tolerant of shade.	8	3	very unlikely
tree	<i>Pinus strobus</i>	eastern white pine			high	insects, seeds	no	Intolerant of soil compaction, sensitive to ozone. Moderately tolerant of shade.	4	3	very unlikely
tree	<i>Platanus occidentalis</i>	sycamore			mod		no	Tolerant of concrete debris and soil compaction, performs well in the right of way. Moderately tolerant of shade.	8	-3	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
tree	<i>Populus balsamifera</i>	balsam poplar			mod	insects, seeds			4	-3	very unlikely
tree	<i>Populus tremuloides</i>	trembling aspen			mod	insects, seeds	mod	Intolerant of soil compaction, sensitive to ozone. Intolerant of shade.	2	0	very unlikely
tree	<i>Prunus serotina</i>	black cherry	May		high	insects, seeds, fruits	yes	Intolerant of soil compaction. Intolerant of shade.	3	3	likely
tree	<i>Quercus macrocarpa</i>	bur oak			high	seeds			5	3	likely
tree	<i>Quercus rubra</i>	northern red oak			high	insects, seeds	yes	Tolerant of soil compaction, tolerant of pollution, performs well in ROW.	6	3	likely
tree	<i>Quercus alba</i>	white oak			high	insects, seeds	yes	Very intolerant of soil compaction, sensitive to ozone, performs well in the right of way. Moderately tolerant of shade.	6	3	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
tree	<i>Quercus bicolor</i>	swamp white oak			mod	insects, seeds	no	Resistant to soil compaction, performs well in the right of way. Moderately tolerant of shade.	8	-3	likely
tree	<i>Salix nigra</i>	black willow	April		high		no	Tolerant of fill soils, concrete debris, and soil compaction. Tolerant of shade.	6	-5	likely
tree	<i>Thuja occidentalis</i>	eastern white cedar			mod	insects, seeds	mod	Intolerant of soil compaction. Moderately tolerant of shade.	4	-3	very unlikely
tree	<i>Tilia americana</i>	American basswood	June		low	insects, seeds	no	Tolerant of concrete; intolerant of soil compaction, performs well in the right of way, minimal tolerance of pollution. Tolerant of shade.	4	3	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
tree	<i>Tsuga canadensis</i>	eastern hemlock			low	insects	no	Intolerant of soil compaction, sensitive to ozone. Tolerant of shade.	7	3	very unlikely
Shrubs											
shrub	<i>Acer spicatum</i>	mountain maple			high	insects, seeds			6	3	very unlikely
shrub	<i>Alnus incana ssp. rugosa</i>	speckled alder			low	seeds			6	-3	extirpated
shrub	<i>Amelanchier alnifolia</i>	saskatoon			high	insects, fruits			8	3	very unlikely
shrub	<i>Amelanchier arborea</i>	downy serviceberry	May		high	insects, fruits	no	Tolerates concrete debris, performs well in the right of way. Moderately tolerant of shade.	5	3	likely
shrub	<i>Amelanchier canadensis</i>	Canadian serviceberry	May		high		mod	Intolerant of soil compaction, sensitive to ozone, performs well in the right of way. Tolerant of shade.			extirpated

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
shrub	<i>Amelanchier laevis</i>	smooth serviceberry	April		mod	insects, fruits	no	Sensitive of soil compaction, sensitive to ozone, performs well in the right of way. Very tolerant of shade.	5	5	unlikely
shrub	<i>Aronia melanocarpa</i>	black chokeberry	May	bees	mod	insects, fruits			7	-3	likely
shrub	<i>Cornus alternifolia</i>	alternate leaved dogwood	June		low	fruits	no	Moderately tolerant of soil compaction. Tolerant of shade.	6	3	very unlikely
shrub	<i>Cornus foemina ssp. racemosa</i>	gray dogwood	June		high	insects, fruits	no	Should tolerate concrete debris, alkaline fill, soil compaction; performs well in ROW. Moderately tolerant of shade.	2	0	likely
shrub	<i>Cornus sericea</i>	red osier dogwood	June		mod	insects, fruits	yes	Tolerant of concrete debris, performs well in ROW.	2	-3	very unlikely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
shrub	<i>Crataegus crus-galli</i>	cockspur hawthorn	May		mod	insects, fruits	yes	Tolerant of compacted soil and various soil pH levels, performs well in the right of way. Tolerant of shade.	4	0	likely
shrub	<i>Diervilla lonicera</i>	bush honeysuckle	July		low	insects, seeds, nectar	no	Tolerant of soil compaction. Tolerant of shade.	5	5	very unlikely
shrub	<i>Elaeagnus commutata</i>	silverberry								3	extirpated
shrub	<i>Hamamelis virginiana</i>	American witch-hazel	Sept				no	Intolerant of soil compaction, performs well in the right of way. Tolerant of shade.	6	3	likely
shrub	<i>Ilex verticillata</i>	common winterberry	May		high	insects, fruits	no	Tolerates soil compaction, performs well in ROW. Moderately tolerant of shade.	5	-3	likely
shrub	<i>Physocarpus opulifolius</i>	eastern ninebark			mod	insects, seeds			5	-3	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
shrub	<i>Prunus virginiana</i>	chokecherry	May		high	insects, fruits	yes	Intolerant of soil compaction, performs well in the right of way and in well-drained fill soils. Moderately tolerant of shade.	2	3	very unlikely
shrub	<i>Rhus typhina</i>	staghorn sumac	July		high	insects, seeds	yes	Intolerant of soil compaction. Intolerant of shade.	1	3	likely
shrub	<i>Salix amygdaloides</i>	peach-leaved willow	May		mod	insects, seeds			6	-3	likely
shrub	<i>Salix bebbiana</i>	Bebb's willow	May		mod	insects, seeds			4	-3	very unlikely
shrub	<i>Salix candida</i>	sage-leaved/hoary willow	May		high				10	-5	very unlikely
shrub	<i>Salix discolor</i>	pussy willow	April		high	insects, seeds			3	-3	unlikely
shrub	<i>Salix interior ssp. exigua</i>	sandbar willow	May		high				1	-3	likely
shrub	<i>Salix lucida</i>	shining willow	May		mod	insects, seeds			5	-3	very unlikely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
shrub	<i>Salix petiolaris</i>	slender willow	May		high				3	-3	likely
shrub	<i>Sambucus canadensis</i>	common elderberry	July		high	insects, fruits	no	Tolerant of soil compaction, probably tolerant of concrete debris. Moderately tolerant of partial shade.	5	-3	likely
shrub	<i>Spiraea alba</i>	narrow-leaved meadowsweet	June		high	insects, fruits	no	Tolerant of soil compaction. Intolerant of shade.	3	-3	likely
shrub	<i>Symphoricarpos albus</i>	thin-leaved snowberry	June		mod	insects, fruits	mod	Tolerant of coarse, medium, and fine soils, intolerant of anaerobic soil. Tolerant of shade.	7	3	very unlikely
shrub	<i>Viburnum acerifolium</i>	maple-leaved viburnum	June		high	insects, fruits	mod	Moderately tolerant of soil compaction. Tolerant of shade.	6	5	unlikely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
shrub	<i>Viburnum lentago</i>	nannyberry	June		mod	insects, fruits	no	Intolerant of soil compaction, should tolerate concrete debris. Moderately tolerant of shade.	4	0	likely
shrub	<i>Viburnum opulus ssp. trilobum</i>	highbush cranberry	June	butterflies	high	insects, fruits	no	Very tough, soil adaptable, performs well in ROW, tolerant of varied soils. Intolerant of shade.	5	-3	very unlikely
Forbs											
forb	<i>Achillea millefolium</i>	common yarrow	June							3	very unlikely
forb	<i>Alisma triviale</i>	common water plantain	July		low	seeds			1	-5	likely
forb	<i>Anemone canadensis</i>	Canada anemone	May	butterflies, insects	low		yes	Tolerant of partial shade.	3	-3	likely
forb	<i>Asclepias incarnata</i>	swamp milkweed	July	butterflies, bees, wasps	high	insects, seeds	no	Adapted to medium and fine soils, high tolerance of soil compaction, performs well in ROW. Intolerant of shade.	6	-5	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
forb	<i>Asclepias syriaca</i>	common milkweed	July	butterflies, bees, wasps, flies, moths	high	insects, seeds	no	Tolerant of fill soils, disturbance, concrete debris. Tolerant of partial shade.	0	5	likely
forb	<i>Astragalus canadensis</i>	Canada milk-vetch	July						8	0	likely
forb	<i>Bidens cernua</i>	nodding beggarticks	July						2	-5	likely
forb	<i>Desmodium canadense</i>	showy tick-trefoil	July					Tolerant of partial shade.	5	0	likely
forb	<i>Doellingeria umbellata</i> (<i>Aster umbellatus</i>)	flat-top white aster	Sept	butterflies, bees	high	insects, seeds		Tolerant of partial shade.	6	-3	very unlikely
forb	<i>Eupatorium perfoliatum</i>	common boneset	July	bees, wasps, butterflies	low	insects		Tolerant of partial shade.	2	-3	likely
forb	<i>Eutrochium maculatum</i>	spotted joe pye weed	Aug	butterflies	high	insects, seeds		Tolerant of partial shade.	3	-5	unlikely
forb	<i>Geum canadense</i>	white avens	June		low		no	Tolerant of partial shade.	3	0	likely
forb	<i>Heliopsis helianthoides</i>	false sunflower	Aug	butterflies	low		no	Performs well in ROW. Tolerant of partial shade.	3	3	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
forb	<i>Liatris spicata</i>	dense blazing-star	Aug	butterflies	high	insects, seeds	no	Tolerant of poor soil, performs well in ROW. Moderately tolerant of shade.	9	0	likely
forb	<i>Lobelia siphilitica</i>	great blue lobelia	July	butterflies, bees	low	nectar		Tolerant of shade.	6	-3	likely
forb	<i>Monarda fistulosa</i>	wild bergamot	July	butterflies, bees	low	nectar	no	Moderately tolerant of shade.	6	3	likely
forb	<i>Penstemon digitalis</i>	foxglove beardtongue	June	butterflies	low	nectar	mod	Adapted to coarse, medium, and fine soils, low tolerance of soil compaction. Tolerant of shade.	6	0	unlikely
forb	<i>Rudbeckia hirta</i>	black-eyed susan	July	butterflies	high	insects, seeds	no	Performs well in ROW. Intolerant of shade.	0	3	likely
forb	<i>Sagittaria latifolia</i>	broad-leaved arrowhead	July				no	Intolerant of shade.	4	-5	likely
forb	<i>Solidago canadensis</i>	Canada goldenrod	Sept		high	insects, seeds	no	Tolerant of fill and concrete. Intolerant of shade.	1	3	likely
forb	<i>Solidago juncea</i>	early goldenrod	May	butterflies	high	insects, seeds		Tolerant of concrete and fill soil. Intolerant of shade.	3	5	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
forb	<i>Sporobolus cryptandrus</i>	sand dropseed			low				2	3	likely
forb	<i>Symphyotrichum cordifolium</i>	heart-leaved aster	Sept	butterflies	high	insects, seeds	no	Intolerant of shade.	5	5	unlikely
forb	<i>Symphyotrichum ericoides</i>	white heath aster	Sept	butterflies	high	insects, seeds		Intolerant of shade.	4	3	likely
forb	<i>Symphyotrichum lateriflorum var. lateriflorum</i>	calico aster	Aug	butterflies	high	insects, seeds			3	0	likely
forb	<i>Symphyotrichum novae-angliae</i>	new England aster	Sept	butterflies	high	insects, seeds	no	Performs well in ROW. Intolerant of shade.	2	-3	likely
forb	<i>Symphyotrichum puniceum</i>	swamp aster	Sept	butterflies	high	insects, seeds			6	-5	very unlikely
forb	<i>Verbena stricta</i>	hoary vervain	July		high	insects, seeds			7	5	unlikely
forb	<i>Verbena urticifolia</i>	white vervain	June		high	insects, seeds		Tolerant of partial shade.	4	0	likely
forb	<i>Zizia aurea</i>	golden alexanders	May		low	insects	mod	Moderately tolerant of shade.	7	0	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
Graminoids											
graminoid	<i>Acorus americanus</i>	American sweetflag			low	seeds	no	Performs well in ROW. Intolerant of shade.	8	-5	likely
graminoid	<i>Agrostis perennans</i>	upland bentgrass			low	seeds	no	High tolerance of soil compaction. Tolerant of partial shade.	5	3	likely
graminoid	<i>Agrostis scabra</i>	rough bentgrass							6	0	very unlikely
graminoid	<i>Andropogon gerardii</i>	big bluestem			high	seeds	mod	Adapted to coarse, medium, and fine soils, moderate tolerance of soil compaction. Intolerant of shade.	7	3	likely
graminoid	<i>Calamagrostis canadensis</i>	bluejoint reedgrass			low	seeds			4	-5	extirpated
graminoid	<i>Carex bebbii</i>	Bebb's sedge			low	seeds			3	-5	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
graminoid	<i>Carex crinita</i>	fringed sedge			low	seeds	no	Adapted to medium and fine soils, high tolerance of soil compaction. Tolerant of partial shade.	6	-5	unlikely
graminoid	<i>Carex scoparia</i>	pointed broom sedge			low	seeds	no	Adapted to medium and fine soils, high tolerance of soil compaction. Tolerant of partial shade.	5	-3	likely
graminoid	<i>Carex stipata</i>	awl-fruited sedge			low	seeds	no	Should tolerate concrete debris. Tolerant of partial shade.	3	-5	likely
graminoid	<i>Carex vulpinoidea</i>	fox sedge			low	seeds	no	Should tolerate concrete debris. Tolerant of partial shade.	3	-5	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
graminoid	<i>Elymus canadensis</i>	Canada wildrye			high	insects, seeds	mod	Adapted to coarse, medium, and fine soils, low tolerance of soil compaction. Tolerant of shade.	8	3	unlikely
graminoid	<i>Elymus hystrix</i>	bottlebrush grass			high	insects, seeds		Tolerant of air pollution. Tolerant of partial shade.	5	5	likely
graminoid	<i>Elymus riparius</i>	eastern riverbank wildrye			high	insects, seeds	no	Adapted to coarse, medium, and fine soils, moderate tolerance of soil compaction. Tolerant of partial shade.	7	-3	likely
graminoid	<i>Elymus virginicus</i>	Virginia wild rye			high	insects, seeds	no	Adapted to coarse, medium, and fine soils, moderate tolerance of soil compaction. Tolerant of partial shade.	5	-3	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
graminoid	<i>Glyceria grandis</i>	tall mannagrass			low	seeds			5	-5	very unlikely
graminoid	<i>Glyceria striata</i>	fowl mannagrass			low	seeds	no	Adapted to coarse, medium, and fine soils, high tolerance of soil compaction. Tolerant of partial shade.	3	-5	likely
graminoid	<i>Juncus effusus</i>	soft rush			low	seeds	no	Adapted to variety of soils, moderate tolerance of soil compaction, performs well in ROW.	4	-5	likely
graminoid	<i>Juncus tenuis</i>	path rush			low	seeds	no	Tolerant of trampling, compacted soil, and fill. Tolerant of partial shade.	0	0	likely
graminoid	<i>Panicum virgatum</i>	old switch panicgrass			low	seeds	mod	Tolerant of sterile, acid, sandy soil, low nutrient fill, performs well in ROW. Tolerant of partial shade.	6	0	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
graminoid	<i>Poa compressa</i>	Canada bluegrass			low	seeds				3	likely
graminoid	<i>Poa palustris</i>	fowl bluegrass			low	seeds			5	-3	unlikely
graminoid	<i>Schizachyrium scoparium</i>	little bluestem			mod	seeds	no	Adapted to coarse, medium, and fine soils, no tolerance of soil compaction. Intolerant of shade.	7	3	likely
graminoid	<i>Scirpus atrovirens</i>	dark-green bulrush					no	Tolerant of disturbance. Tolerant of partial shade.	3	-5	likely
graminoid	<i>Sorghastrum nutans</i>	yellow prairie-grass					no	Tolerant of urban conditions, performs well in ROW. Intolerant of shade.	8	3	likely
graminoid	<i>Sporobolus michauxianus (Spartina pectinata)</i>	prairie cordgrass			low	seeds	no	Should be tolerant of concrete debris. Intolerant of shade.	7	-3	likely
graminoid	<i>Typha latifolia</i>	broad-leaved cattail					no	Intolerant of shade.	1	-5	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tolerance	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)
Aquatics											
aquatic	<i>Callitriche hermaphroditica</i>	autumnal water-starwort							10	-5	likely
aquatic	<i>Ceratophyllum demersum</i>	common hornwort							4	-5	likely
aquatic	<i>Elodea canadensis</i>	broad waterweed							4	-5	likely
aquatic	<i>Myriophyllum sibiricum</i>	Siberian water-milfoil							6	-5	likely
aquatic	<i>Nuphar variegata</i>	variegated pond-lily							7	-5	extirpated
aquatic	<i>Nymphaea odorata</i>	fragrant water-lily							5	-5	likely
aquatic	<i>Potamogeton amplifolius</i>	large-leaved pondweed							5	-5	unlikely
aquatic	<i>Potamogeton natans</i>	floating pondweed							5	-5	likely
aquatic	<i>Potamogeton pusillus</i>	small pondweed							4	-5	likely
aquatic	<i>Vallisneria americana</i>	eel-grass							6	-5	likely

Appendix B: Proposed Plant Species Additions from Ontario’s Carolinian Zone

Table B1. Species to supplement Lake Simcoe Region Conservation Authority’s planting list from Ontario’s Carolinian zone, including (if available) flowering season for insect-pollinated species, type of insect pollinator, ranking of importance as a food source for migrating birds (Impt. as a Food Source for Migr. Birds), and type of food provided (Martin et al., 1951; Tallamy, 2007; NYC, 2014; CVC, 2015; Audubon Great Lakes, 2024). Details about salt tolerance (Salt Tol.) and urban tolerance, if available, were sourced from NYC Parks (2014). Coefficient of Conservatism (Coeff. of Cons.) and Coefficient of Wetness (Coeff. of Wet.) were sourced from the Natural Heritage Information Centre (Oldham, 2017). Likelihood of persistence to mid- and late-century is reported from Canada’s Plant Hardiness Site (NRC, 2022). Other abbreviations are as follows: “mod” = Moderate. “ROW” = Right of Way.

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
Trees												
tree	<i>Carpinus caroliniana</i>	blue-beech			mod	fruits, seeds	no	Sensitive to soil compaction. Performs well in ROW. Tolerant of shade.	6	0	likely	likely
tree	<i>Carya glabra</i>	pignut hickory			high	seeds	no	Intolerant of soil compaction. Moderately tolerant of shade.	9	3	likely	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
tree	<i>Populus deltoides</i>	eastern cottonwood			mod	insects, seeds	yes	Tolerant of soil compaction and disturbed soil. Intolerant of shade.	4	0	likely	likely
tree	<i>Quercus palustris</i>	pin oak			high	insects, seeds	no	Sensitive to soil compaction, tolerant of sulfur dioxide, performs well in ROW. Intolerant of shade.	9	-3	likely	likely
tree	<i>Quercus prinoides</i>	dwarf chestnut oak			high	insects, seeds		Should tolerate concrete debris, intolerant of soil compaction. Intolerant of shade.	10	3	likely	likely
tree	<i>Sassafras albidum</i>	sassafras	May		low	insects	yes	Intolerant of soil compaction. Intolerant of shade.	6	3	likely	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
Shrubs												
shrub	<i>Corylus americana</i>	American hazelnut			mod	fruits	no	Moderately tolerant of soil compaction. Tolerant of partial shade.	5	3	likely	unlikely
shrub	<i>Lindera benzoin</i>	spicebush	April		mod	insects, fruits	mod	Somewhat tolerant of urban pollution, performs well in the right of way. Tolerant of shade.	6	-3	likely	unlikely
shrub	<i>Rhus copallina</i>	winged sumac			high	fruits	yes	Intolerant of soil compaction.	7	5	likely	unlikely
shrub	<i>Rubus flagellaris</i>	northern dewberry	June		high	insects, fruits	no	Tolerant of concrete debris. Intolerant of shade.	4	3	likely	unlikely
shrub	<i>Staphylea trifolia</i>	American bladdernut	May		low		no	Tolerant of shade.	7	0	likely	unlikely
shrub	<i>Vaccinium pallidum</i>	early lowbush blueberry	June		high	fruits		Tolerant of partial shade.	9	5	likely	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
Forbs												
forb	<i>Actaea racemosa</i>	black snakeroot	July	butterflies	low		mod	Somewhat tolerant of urban pollution. Tolerant of shade.			likely	likely
forb	<i>Aquilegia canadensis</i>	wild columbine	May	bees	low	nectar	no		5	3	likely	likely
forb	<i>Borodinia canadensis (Arabis canadensis)</i>	sicklepod rockcress	June	bees, flies			no	Tolerant of shade.	7	5	likely	unlikely
forb	<i>Caulophyllum thalictroides</i>	blue cohosh	May	bees	low		no	Adapted to medium soils, low compaction tolerance, partial shade tolerance.	5	5	likely	unlikely
forb	<i>Collinsonia canadensis</i>	Canada horse-balm	Aug					Tolerant of shade.	8	0	likely	likely
forb	<i>Dicentra cucullaria</i>	dutchman's breeches	April	butterflies, bees	low			Tolerant of shade.	6	5	likely	likely
forb	<i>Geranium maculatum</i>	spotted geranium	April		low	seeds		Performs well in ROW, tolerant of shade.	6	3	likely	unlikely
forb	<i>Helianthus giganteus</i>	tall sunflower	Aug		high	insects, seeds		Tolerant of shade.	6	-3	likely	unlikely
forb	<i>Krigia virginica</i>	Viginia dwarf-dandelion						Intolerant of shade.	10	5	likely	unlikely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
forb	<i>Lespedeza capitata</i>	round-headed bush-clover			mod		no	Tolerant of partial shade.	7	3	likely	unlikely
forb	<i>Lespedeza hirta</i>	hairy bush-clover	Aug	butterflies	mod	seeds	no	Tolerant of partial shade.	9	5	likely	likely
forb	<i>Monarda punctata</i>	spotted beebalm	Aug	butterflies			mod	Intolerant of shade.	4	5	likely	unlikely
forb	<i>Osmorhiza claytonii</i>	hairy sweet cicely	June	butterflies				Tolerant of shade.	5	0	likely	unlikely
forb	<i>Peltandra virginica</i>	green arrow arum					mod	Tolerant of concrete debris, tolerant of shade	9	-5	likely	likely
forb	<i>Persicaria hydropiperoides</i> (<i>Polygonum hydropiperoides</i>)	false waterpepper	Aug		mod		no	Tolerant of partial shade.	4	-5	likely	unlikely
forb	<i>Polygonatum biflorum</i>	honey-flowered solomon's seal	May		low	fruit		Tolerant of partial shade.	8	3	likely	likely
forb	<i>Pontederia cordata</i>	pickerel weed	Aug		mod		yes	Tolerant of alkaline fill and concrete debris, tolerant of partial shade.	7	-5	likely	unlikely
forb	<i>Saururus cernuus</i>	lizard's-tail					mod	Tolerant of shade.	8	-5	likely	unlikely
forb	<i>Solidago bicolor</i>	white goldenrod	Sept	bees	high	insects, seeds		Tolerant of partial shade.	8	5	likely	likely
forb	<i>Trichostema dichotomum</i>	forked bluecurls	Sept	bees				Tolerant of shade.	8	5	likely	unlikely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
forb	<i>Viola pubescens</i>	yellow violet	April	butterflies	low		no	Tolerant of shade.	5	3	likely	unlikely
Graminoids												
graminoid	<i>Aristida purpurascens</i>	arrowfeather threeawn grass						Tolerates concrete debris, intolerant of shade.	10	5	likely	likely
graminoid	<i>Carex pennsylvanica</i>	Pennsylvania sedge			low	seeds		Prefers open shade.	5	5	likely	unlikely
graminoid	<i>Carex radiata</i>	eastern star sedge			low	seeds		Tolerant of shade.	4	0	likely	unlikely
graminoid	<i>Carex rosea</i>	rosy sedge			low	seeds		Tolerant of shade.	2	5	likely	unlikely
graminoid	<i>Carex stricta</i>	tussock sedge			low	seeds	no	Adaptable, moderate tolerance of soil compaction, performs well in ROW, tolerant of partial shade.	4	-5	likely	unlikely
graminoid	<i>Carex swanii</i>	swan's sedge			low	seeds		Tolerates disturbed habitats, tolerant of shade.	7	3	likely	unlikely
graminoid	<i>Carex virescens</i>	ribbed sedge			low	seeds		Tolerant of partial shade.	7	3	likely	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
graminoid	<i>Dichanthelium clandestinum</i>	deer-tongue panicgrass			low	seeds	no	Adapted to coarse, medium, and fine soils, low tolerance of soil compaction. Intolerant of shade.	8	-3	likely	unlikely
graminoid	<i>Dichanthelium latifolium</i>	broad-leaved panicgrass			low	seeds	no	Adapted to coarse and medium soils, no tolerance of soil compaction. Moderately tolerant of shade.	6	3	likely	unlikely
graminoid	<i>Dulichium arundinaceum</i>	three-way sedge			low	seeds	no	Adapted to coarse, medium, and fine soils, moderate tolerance of soil compaction. Tolerant of partial shade.	7	-5	likely	likely
graminoid	<i>Rhynchospora capitellata</i>	small-headed beakrush			low	seeds		Intolerant of shade.	10	-5	likely	likely

Type of Plant	Scientific Name	Common Name	Flowering Season	Insect Pollinator	Impt. as Food Source for Migr. Birds	Food Type	Salt Tol.	Urban Tolerance	Coeff. of Cons.	Coeff. of Wet.	Likelihood of Persist. (mid-century, high emissions)	Likelihood of Persist. (late-century, high emissions)
Vines												
vine	<i>Menispermum canadense</i>	Canada moonseed	July		high	fruits	no	Tolerant of soil compaction. Tolerant of partial shade.	7	0	likely	unlikely
vine	<i>Vitis riparia</i>	riverbank grape	June		high	insects, fruits	yes	Tolerant of soil compaction and concrete debris. Tolerant of shade.	0	0	likely	unlikely

Appendix C: Caveats and Considerations

We outlined some considerations and caveats associated with interpretation of the results. Table C1 below outlines each consideration/caveat and associated implications for interpretation.

Table C1. Considerations and caveats of this analysis.

Consideration/Caveat	Implication
<p>The persistence of species on Lake Simcoe Region Conservation Authority’s planting list may be additionally impacted by unforeseen or unpredictable future climate conditions or impacts outside the scope of this analysis.</p>	<p>Persistence scoring was based only on outputs of modelled, mid-century climate envelopes under a high emissions scenario (Representative Concentration Pathway 8.5). There are several climate and non-climate related factors which could change the outcome of these predictions, including, but not limited to:</p> <ul style="list-style-type: none"> • New/unforeseen pests or disease impacting survivability of species in the future (e.g. oak wilt); • Increasing urban sprawl, land use change, and pollution could impact the health of ecosystems across the watershed; • Wildfires, which could become an issue across the watershed if drought conditions become common, posing a risk to entire vegetation communities; • Phenological asynchrony (e.g. misalignment in timing of flowering and visitation of pollinators) greatly impacting the ability of plant species to persist in the watershed; • Plant species not able to keep up with the pace of climate change and migrate into their future predicted climate envelopes; • Climate change and related impacts being either more or less intense than predicted under a high-emissions scenario (Representative Concentration Pathway 8.5).
<p>Reference more models to increase robustness of predictions of mid-century persistence within the Lake Simcoe Watershed.</p>	<p>Due to time constraints and availability of models, analysis of future persistence of plant species in the watershed was based on an average output of only two models. Increasing the number of models referenced (if possible) would increase the robustness of predicting future species persistence.</p>
<p>Future climate may advance the timing of leaf out, flowering, and fruiting of plants on the planting list by over a month (LSRCA, 2020).</p>	<p>Extra attention should be directed to plants on the planting list that are important for plant-wildlife interactions, as the degree of phenological asynchrony may increase. This could impact the value/success of the recommended actions related to plant-wildlife interactions from this report.</p>

Consideration/Caveat	Implication
Sourcing seed and seedlings of Carolinian species to enhance and build resiliency in the planting list could be difficult.	It may be challenging to enhance the planting list as recommended if seed/seedling sources for Carolinian species are limited in Ontario. Additionally, there may be restrictions on seed/stock sourcing under the currently widely adopted seed zone guidelines which limit movement between seed zones, though this may change as the new seed transfer policy is implemented.
Rarity of Carolinian zone species could change with future range shifts.	Future climate conditions may make Carolinian species more or less common within the watershed.
Site-specific considerations for species selection should be paired with considerations about plant-wildlife interactions, particularly regarding pollination and food-provisioning.	Future restoration projects should consider selecting species which provide pollination or food provisioning services under a mid-century climate scenario to promote alignment of plant-wildlife interactions in the future.

Appendix D: Future Directions and Next Steps

This analysis inspired additional future actions and directions for consideration, should resources become available. Table D1 below outlines future directions for additional action, monitoring, or research based on the outcomes of this analysis.

Table D1. Future directions for monitoring, analyses, and action.

Future Direction	Implication	Required Resources/Actions
Create accessible content for the public and other audiences to disseminate key findings of this report.	Adapting/tailoring content for presentation to several different audiences could promote wide-adoption of the recommendations from this report. This could include a non-technical list of species for the public, or presentations to different audiences.	Create a non-technical and accessible plant list for the public and related audiences for our website that can be distributed to landowners, municipalities, and community groups.
Continue to monitor future climate envelope models and range shifts of species to adapt the planting list as needed. This will help ensure that the list remains resilient to climate change.	Predictions of climate envelopes may change in the future, impacting the persistence of species recommended for planting in the watershed. The planting list needs to adapt and align with the most up-to-date information from climate envelope models.	Monitor NRC's Plant Hardiness Site for updates to climate envelope models, and update the planting list as needed/as climate projections are updated.
Integrate trait-based assessments and assessments of vulnerability to existing and future non-climate threats into persistence scoring.	Species characteristics (e.g. genetic variability, dependence on other species, and sensitivity to pests and disease) and other threats to species persistence (e.g. population dynamics of pests and disease, land use change/habitat loss, and habitat degradation/pollution) should be incorporated into scoring.	Research additional, non-climate related threats to plant species persistence across the watershed and incorporate into persistence scoring.
Track the timing of leaf out, flowering, and fruiting for plant species on the planting list which are important to plant-wildlife interactions.	The degree of asynchrony of plant-wildlife interactions may increase if plant species advance leaf out and flowering, impacting pollination and food provisioning for migrating birds.	Monitor and model future leaf out, flowering, and fruiting times of plants on the planting list, especially for species that are very unlikely to persist or will be extirpated. Supplement the list as needed to fill gaps in pollination or food-provisioning services.

Future Direction	Implication	Required Resources/Actions
<p>Monitor the success of using an updated plant list, and application of assisted migration. How do the new Carolinian additions fare compared to the existing plant list species?</p>	<p>This could help us better understand assisted migration as a strategy, and adaptively manage/modify the recommendations for this report to better target future climate scenarios. This can also help us to ensure that recommended species that develop invasive tendencies can be removed from the list.</p>	<p>Monitor planting projects where recommended species from Ontario’s Carolinian zone have been planted.</p>
<p>Work with First Nations across the watershed on climate resilient planting, including:</p> <ul style="list-style-type: none"> • supporting First Nations with identifying the culturally significant plant species at risk under climate change and the supplementation of species from southern ecozones; and • exploring additional species with a cultural significance and supplementing the current list with these species that will be resilient to mid-century climate in the watershed. 	<p>Finding opportunities to collaborate with and support needs of First Nations would be beneficial to build a fulsome approach to climate resiliency. Cultural significance needs to be addressed by integrating traditional ecological knowledge in partnership with First Nations.</p>	<p>Work with First Nation partners and share knowledge with respect to planting climate resilient species that are of cultural significance.</p>

Future Direction	Implication	Required Resources/Actions
<p>Consider climate impacts on other important ecosystem services provided by species on the current planting list, and, if these services will be impacted, supplement the list to fill gaps.</p>	<p>Although out of scope of this analysis, there are several other important ecosystem services provided by plants on the list which will be impacted by climate change (e.g. carbon sequestration, habitat provisioning, stormwater management, erosion control, ecological buffers to the natural heritage system, temperature moderation, etc.). If species on the list are selected in a restoration project for a specific service they provide, it will be important to ensure that the species will persist in the watershed and maintain their capacity to deliver the ecosystem service.</p>	<p>Monitor the scientific literature for emerging research about impacts of climate change on other ecosystem services in the watershed.</p> <p>Analyze the current planting list through the lens of capacity to provide other ecosystem services.</p> <p>Supplement the planting list as needed to include climate resilient species important for these other ecosystem services.</p>
<p>Expand climate vulnerability assessments to a larger spatial scale. Undertake a climate vulnerability assessment of vegetation communities across the Lake Simcoe Watershed to help inform and target priority locations for restoration. Map the output to visualize vulnerable communities across the watershed.</p>	<p>Climate change will have different impacts on different vegetation communities in the Lake Simcoe Watershed. The vulnerability of vegetation communities as a whole should be assessed to help prioritize locations of restoration and afforestation sites in the future.</p>	<p>Conduct a climate vulnerability assessment on vegetation communities across the watershed, paired with a detailed inventory of vegetation communities and consultation of climate models/additional threats (e.g. invasive species, wildfires, disease).</p>
<p>Fill information gaps regarding salt and urban tolerance.</p>	<p>More information about tolerance to salt and urban environments can help inform species selection for planting around roads and/or within settlements.</p>	<p>Monitor emerging research and take opportunistic notes about urban and salt tolerance of species during field work/site visits.</p>

Future Direction	Implication	Required Resources/Actions
<p>Increase research and monitoring of the effects of climate change on aquatic vegetation (i.e. submergent and floating) and plant-wildlife interactions in these ecosystems to promote climate adaptation for aquatic restoration.</p>	<p>Lake Simcoe Region Conservation Authority’s Restoration program focuses mainly on terrestrial restoration at this time, but restoration of aquatic habitats may become more prominent in the future. More research is needed to inform considerations for appropriate species selection for aquatic ecosystems in light of climate impacts, including climate envelope shifts and impacts to plant-wildlife interactions.</p>	<p>Conduct more research on vulnerability of aquatic communities to climate change and plant-wildlife interactions in these communities.</p>