Climate Change Research Report CCRR-48

Climate change vulnerability assessment of species in the Ontario Great Lakes Basin

Ministry of Natural Resources and Forestry

Ontario

Climate change vulnerability assessment of species in the Ontario Great Lakes Basin

Samuel R. Brinker, Mary Garvey, and Colin D. Jones

Natural Heritage Information Centre, Science and Research Branch, Ontario Ministry of Natural Resources and Forestry, 300 Water St. N., Peterborough, ON, Canada, K9J 3C7

2018

Printed in Ontario, Canada

Single copies of this publication are available from info.mnrfscience@ontario.ca.

Cette publication hautement spécialisée, Climate Change Vulnerability Assessment of Species in the Ontario Great Lakes Basin, n'est disponible qu'en anglais en vertu du Règlement 671/92 qui en exempte l'application de la Loi sur les services en français. Pour obtenir de l'aide en français, veuillez communiquer avec le ministère des Richesses naturelles au climatechangemnr@ontario.ca.

Cover photo: Bear's Rump Island, Georgian Bay (Sam Brinker).

Some of the information in this document may not be compatible with assistive technologies. If you need any of the information in an alternate format, please contact climatechangemnr@ontario.ca.

This paper contains recycled materials.

Cite this report as:

Brinker, S.R., M. Garvey and C.D. Jones. 2018. Climate change vulnerability assessment of species in the Ontario Great Lakes Basin. Ontario Ministry of Natural Resources and Forestry, Science and Research Branch, Peterborough, ON. Climate Change Research Report CCRR-48. 85 p. + append.

Summary

Traditional natural resource planning, management, and monitoring are often based on the assumption that species distributions will remain relatively stable. This fundamental assumption is being challenged however, in light of rapid climate change. Climate change *will* affect the distribution and abundance of species in the Ontario Great Lakes Basin. Accordingly, scientists, resource managers, planners, conservationists, and policymakers have stressed the need to identify and implement strategies for adapting to the effects of climate change. Understanding which species are likely to be vulnerable and which traits make them vulnerable is vital to developing effective adaptation strategies.

To better understand the potential effects of climate change on our natural resources, the Ministry of Natural Resources and Forestry's Natural Heritage Information Centre, the ministry's Climate Change Program, and the Canada-Ontario Agreement Respecting the Great Lakes Basin began a multi-year project to assess the vulnerability of species in the Ontario Great Lakes Basin, focusing on species of conservation concern. *Vulnerability* is the degree to which a species is susceptible to and unable to cope with the adverse effects of climate change. In this assessment, we provide an overview of how climate change is likely to affect a subset of both common species and species of conservation concern in the near future (2041–2071). The goals of this assessment were to:

1. Assess a representative subset of species of conservation concern (and some common species) in the Ontario Great Lakes Basin to determine their climate change vulnerability
2. Assess patterns of vulnerability across major taxonomic groups
3. Determine the relative vulnerability of species for each Great Lake watershed
4. Highlight relationships between species vulnerability and conservation status
5. Share results broadly to spotlight species vulnerability and encourage the development of adaptation strategies that help build resilience

We used NatureServe's Climate Change Vulnerability Index (CCVI) to assess the relative vulnerability of 280 species in Ontario's Great Lakes basin to climate change. The index incorporates a framework that separates a species' vulnerability into 2 main components: the species' exposure to climate change in the Ontario Great Lakes Basin and its sensitivity/ adaptive capacity. The assessment is based on projected changes in temperature and moisture from both recent historical (1960–1990) records and near-future projections (2041–2071, which we refer to as the 2050s). Climate projections for the 2050s period were downscaled from the Intergovernmental Panel on Climate Change Fifth Assessment Report representative concentration pathways scenario 4.5 (RCP4.5), averaged from 15 general circulations models (GCM) using AdaptWest at 1 km resolution. In calculating relative risk, the index relies on predictions about the magnitude of change in temperature and precipitation across the species' range in the study area. Due to the number of species assessed, a single climate scenario was selected to illustrate potential effects. Species were scored against 20 sensitivity and indirect exposure factors with scores falling into 1 of several categories: neutral, somewhat increased vulnerability, increased vulnerability, and greatly increased vulnerability. The outcome was 1 of 5 possible index categories: 3 degrees of vulnerable (extremely, highly, moderately), less vulnerable, and insufficient evidence.

The 280 species assessed spanned 10 major taxonomic groups: amphibians, birds, bryophytes (mosses and liverworts), fishes, insects and spiders, lichens, mammals, molluscs, reptiles, and vascular plants. Selected species met 1 or more of the following conditions:

1. Are suspected of being susceptible to climate change directly or indirectly (i.e., restricted to or rely on colder than normal microclimates)
2. Are habitat specialists or keystone species
3. Are of conservation concern, i.e., either globally rare or provincially rare or federally or provincially listed species at risk
4. Are at their southern or northern range limits or endemic to the Ontario Great Lakes Basin
5. Have sufficient distributional and ecological data to allow for an assessment.

Our results showed 175 of the 280 assessed species to be vulnerable to climate change. Eleven were found to be extremely vulnerable, 49 were highly vulnerable, and 115 were moderately vulnerable. The remaining 105 were found to be less vulnerable. Of the 10 taxonomic groups assessed, those depending most on water (molluscs, fishes, amphibians, lichens) were most vulnerable. Vascular plants and mammals varied widely in assessed vulnerability, while birds, insects and spiders, and reptiles were found to be the least vulnerable. The common risk factor for all groups was historical hydrological niche or species' past exposure to precipitation variations across its range in the Ontario Great Lakes Basin (and hence potential ability to adapt to future change depending on the magnitude). A species' temperature tolerance, dispersal ability, barriers to movement, habitat specificity, and hydrological requirements were other important traits contributing to its climate change vulnerability.

We found that the Lake Superior Basin had the highest proportion of species (64%) likely to be vulnerable to climate change and the most species (26%) found to be extremely vulnerable. Results suggested that, throughout the basin, the highest concentrations of the most vulnerable species are associated with these ecosystems:

- Canyons with glacière talus and arctic-alpine bedrock shorelines in the Lake Superior Basin
- Extensive dune and coastal wetland complexes of lakes Erie and Huron
- Several large meandering rivers draining large areas of the Lake Erie basin concentrated in the Carolinian Life Zone in southwestern Ontario

More than 80% of species of global or provincial conservation concern or at risk of extinction according to the Committee on the Status of Species at Risk in Ontario (COSSARO) were found to be vulnerable to climate change. However, species with a high conservation status were not always more vulnerable than secure or apparently secure ones. Only 24% of global conservation concern species were vulnerable, while 59% of globally secure and apparently secure species were vulnerable.

Provincial species of conservation concern were more vulnerable than secure and apparently secure species, with 68% of provincial conservation concern species vulnerable to climate change and 42% of provincially secure and apparently secure species vulnerable. Species that COSSARO assessed as at risk of extinction were only marginally more vulnerable (65%) to climate change than unlisted species and those listed as not at risk (62%).

The information we produced about the projected effects of climate change on 280 species may serve as surrogates for the vulnerability of other species with similar needs or at least inform managers of likely species responses to projected changes in climate. Results support the development of adaptive conservation strategies aimed at mitigating identified vulnerabilities. They also highlight the importance of considering climate change in managing species at risk and the need for better, more coordinated, and centralized biodiversity and distribution data for all species of conservation concern, particularly invertebrates, lichens, and bryophytes, for which information is limited. Finally, our work provides a template for similar or expanded analyses as new data become available or conditions change. Future vulnerability assessments should include more common and widespread species.

Resumé

Évaluation de la vulnérabilité au changement climatique de la biodiversité dans le bassin des Grands Lacs de l'Ontario

La planification, la gestion et la surveillance des ressources naturelles s'appuient bien souvent sur une hypothèse de répartitions des espèces stables. Cette hypothèse fondamentale est cependant remise en question dans le contexte actuel de changement climatique rapide. Le changement climatique affectera entre autres la répartition et l'abondance des espèces dans le bassin versant des Grands Lacs de l'Ontario. Par conséquent, des scientifiques, des chefs de la gestion des ressources, des planificatrices et des planificateurs des ressources, des environnementalistes et des responsables des politiques ont insisté sur l'importance de définir et de mettre en œuvre des stratégies d'adaptation aux effets du changement climatique. Savoir quelles espèces sont vulnérables au changement climatique, et comprendre ce qui les rend vulnérables, contribue certainement à l'élaboration de stratégies d'adaptation efficaces.

Pour mieux cerner les effets potentiels du changement climatique sur nos ressources naturelles, le Centre d'information sur le patrimoine naturel du ministère des Richesses naturelles et des Forêts, le programme en matière de changement climatique du ministère et l'Accord Canada-Ontario sur la qualité de l'eau et la santé de l'écosystème des Grands Lacs, ont lancé un projet pluriannuel d'évaluation de la vulnérabilité des espèces dans le bassin des Grands Lacs de l'Ontario axé sur les espèces dont la conservation est préoccupante. La vulnérabilité correspond à l'exposition d'une espèce aux effets du changement climatique, et à sa capacité d'y faire face. L'évaluation de la vulnérabilité donne une vue d'ensemble des effets que le changement climatique pourrait avoir sur les espèces dans un avenir proche (2041 à 2071). Les objectifs étaient les suivants :

1. Évaluer un sous-ensemble représentatif d'espèces rares (et de certaines espèces communes) dans le bassin des Grands Lacs de l'Ontario pour déterminer leur vulnérabilité au changement climatique.
2. Évaluer les tendances concernant la vulnérabilité chez les principaux groupes taxonomiques.
3. Déterminer la vulnérabilité relative des espèces pour le bassin versant de chaque Grand Lac.
4. Établir des liens entre la vulnérabilité des espèces et leur taux de conservation.
5. Diffuser les résultats à grande échelle pour attirer l'attention sur la vulnérabilité des espèces et encourager l'élaboration de stratégies d'adaptation visant à favoriser leur résilience.

Nous avons utilisé l’indice de vulnérabilité au changement climatique de NatureServe pour évaluer la vulnérabilité relative de 280 espèces dans le bassin des Grands Lacs de l’Ontario. L’indice repose sur un cadre qui distingue 2 composantes principales concernant la vulnérabilité d’une espèce : son exposition au changement climatique dans bassin des Grands Lacs de l’Ontario et sa sensibilité au changement climatique. L’évaluation se base sur les variations projetées de la température et de l’humidité établies à partir de registres historiques récents (de 1960 à 1990) et de projections sur une période rapprochée (de 2041 à 2071, dénommée les années 2050). Les projections climatiques pour cette période ont été ramenées à une plus petite échelle par rapport au scénario 4.5 des profils représentatifs d’évolution de concentration du cinquième rapport d’évaluation du Groupe d’experts intergouvernemental sur l’évolution du climat, suivant une moyenne tirée de 15 modèles de circulation générale, à l’aide d’AdaptWest, avec une résolution d’un kilomètre. En calculant le risque relatif, l’indice utilise des prévisions de l’ampleur des variations de la température et des précipitations dans l’aire de répartition d’une espèce. En raison du nombre d’espèces évaluées, un seul scénario climatique a été retenu pour illustrer les effets potentiels. Les espèces ont été évaluées selon 20 facteurs d’exposition indirecte ou de sensibilité, et les résultats entrent dans l’une des catégories suivantes : neutre, légère augmentation de la vulnérabilité, augmentation de la vulnérabilité et augmentation importante de la vulnérabilité. L’indice prévoit en outre 5 classifications selon les résultats : 3 classes de vulnérabilité (« extrêmement vulnérable », « hautement vulnérable » et « modérément vulnérable »), « non vulnérable » et « données insuffisantes ».

Les 280 espèces évaluées appartenaient à 10 principaux groupes taxonomiques : les plantes vasculaires, les bryophytes (les mousses et les hépatiques), les lichens, les mollusques, les insectes et les araignées, les amphibiens, les reptiles, les poissons, les mammifères et les oiseaux. Les espèces sélectionnées remplissaient au moins une des conditions suivantes :

1. Elles sont susceptibles d’être vulnérables au changement climatique de manière directe ou indirecte (elles sont circonscrites à des microclimats plus froids que la normale, ou elles en dépendent, par exemple).
2. Elles sont des espèces spécialistes de l’habitat ou des espèces clés.
3. Il s'agit d'espèces dont la conservation est préoccupante, c’est-à-dire qu’elles sont rares à l’échelle mondiale ou provinciale, ou qu’elles figurent sur la liste fédérale ou provinciale des espèces en péril.
4. Elles se trouvent à la limite nord ou sud de leur aire de répartition, ou elles sont endémiques dans le bassin des Grands Lacs de l’Ontario.
5. Suffisamment de données sur la répartition et de données écologiques permettent leur évaluation.

Les résultats de l’évaluation démontrent que 175 des 280 espèces évaluées étaient vulnérables au changement climatique. Parmi ces espèces vulnérables, 11 d’entre elles étaient extrêmement vulnérables, 49 étaient hautement vulnérables, et 115 étaient modérément vulnérables. Les 105 espèces restantes étaient non vulnérables. Parmi les 10 groupes taxonomiques évalués, les plus vulnérables au changement climatique étaient les mollusques, les poissons, les amphibiens et les lichens. Chez les plantes vasculaires et les mammifères, la vulnérabilité variait grandement. Enfin, les oiseaux, les insectes et les araignées ainsi que les reptiles étaient les espèces les moins vulnérables. Le facteur de risque commun à tous les groupes était la niche hydrologique historique ou l’exposition passée d’une espèce à des variations de précipitations dans son aire de répartition dans le bassin des Grands Lacs de l’Ontario (elles pourraient donc s’adapter aux variations futures, selon leur ampleur). La tolérance à la température, la capacité de dispersion, les obstacles au déplacement, les particularités de l’habitat ainsi que les besoins hydrologiques d’une espèce comptaient parmi les autres caractéristiques qui contribuent à la vulnérabilité au changement climatique.

Le Bassin du lac Supérieur avait la plus haute proportion d’espèces (64 %) susceptibles d’être vulnérables au changement climatique et le plus grand nombre d’espèces (26 %) classées comme étant extrêmement vulnérables. Les résultats indiquent que les plus grandes concentrations d’espèces les plus vulnérables sont liées à différents écosystèmes, dont les canyons avec des *glacière talus* et les littoraux rocheux arctiques-alpins dans le bassin du lac Supérieur, les dunes et les complexes de terres humides côtières du lac Érié et du lac Huron, ainsi que plusieurs grandes rivières sinueuses qui drainent les étendues du bassin du lac Érié, dans la zone biologique carolinienne du Sud-Ouest de l'Ontario.

Plus de 80 % des espèces dont la conservation est préoccupante à l’échelle mondiale ou provinciale, ou qui présentent un risque d’extinction selon le Comité de détermination du statut des espèces en péril en Ontario (CDSEPO), étaient aussi vulnérables au changement climatique. Cependant, les espèces ayant un statut de conservation élevé n’étaient pas toujours plus vulnérables que les espèces dites non en péril ou apparemment non en péril. Seulement 24 % des espèces dont la conservation est préoccupante à l’échelle mondiale étaient vulnérables au changement climatique, tandis que 59 % des espèces non en péril et apparemment non en péril à l’échelle mondiale l’étaient. En revanche, les espèces dont la conservation est préoccupante à l’échelle provinciale étaient plus vulnérables que les espèces non en péril et apparemment non en péril. En effet, 68 % des espèces dont la conservation est préoccupante à l’échelle provinciale étaient vulnérables au changement climatique, tandis que 42 % des espèces non en péril et apparemment non en péril à l’échelle provinciale l’étaient. Les espèces présentant des risques d’extinction selon le CDSEPO n’étaient que légèrement plus vulnérables au changement climatique (65 %) que les espèces non répertoriées et celles classées comme n’étant pas en péril.

Le rapport traite des effets projetés du changement climatique sur 280 espèces, lesquelles peuvent servir de substituts pour évaluer la vulnérabilité d’autres espèces ayant des besoins similaires. Ils renseigneront à tout le moins les chefs de la gestion des ressources sur les réactions probables des espèces aux variations projetées du climat.

Ces résultats pourront servir à l’élaboration de stratégies de conservation d’adaptation face aux vulnérabilités observées. L’analyse met en lumière l’importance de tenir compte du changement climatique dans la gestion des espèces en péril et la nécessité d’avoir en main de meilleures données, mieux coordonnées et davantage centralisées, au sujet de la biodiversité et de la distribution pour toutes les espèces dont la conservation est préoccupante, surtout pour les invertébrés, les lichens et les bryophytes, au sujet desquels les données se font rares. Enfin, le rapport fournit un modèle pour la réalisation d’analyses similaires ou plus poussées lorsque de nouvelles données seront disponibles ou lorsque les conditions changeront. De futures évaluations de la vulnérabilité sont d’ailleurs nécessaires et devraient inclurent d’autres espèces plus communes et plus répandues.

Acknowledgements

Support for this project was provided by the Ministry of Natural Resources and Forestry (MNRF), the Canada-Ontario Agreement Respecting the Great Lakes Basin, NatureServe Canada, and NatureServe.

This project could not have come to fruition without the assistance and support of many people. Special thanks to Jim Mackenzie for championing the project and for providing leadership throughout its completion. We also extend our thanks to Gary Nielson, Paul Gray, Jenny Gleeson, Rachel Gagnon, Cori Carveth, and Paulette Hebert, who helped coordinate the Great Lakes Basin Climate Change Vulnerability Assessment (CCVI). We also acknowledge Bruce Young of NatureServe for help using the Climate Change Vulnerability Index and guidance on interpreting results, as well as thoughtful review. Stephanie Auer of NatureServe provided downscaled climate rasters for the Ontario Great Lakes Basin. We also thank Emma Horrigan of Ontario Nature and MNRF's Rob Craig, Tanya Taylor, and Adam Hogg for technical support and assistance.

Several experts reviewed individual species assessments. In particular we thank MNRF's Don Sutherland and Al Dextrase for providing feedback on intrinsic factors and CCVI scores for aquatic species and mammals.

Valued technical review of all or portions of this report was provided by MNRF's Michael J. Oldham, Stephen Mayor, Jenny Gleeson, and several staff from Species Conservation Policy Branch.

Data for this project was provided by MNRF's Natural Heritage Information Centre, Bird Studies Canada, Department of Fisheries and Oceans Canada, Ontario Nature, the Consortium of North American Lichen Herbaria, and the Consortium of North American Bryophyte Herbaria.

Three examples of the 280 species assessed as part of a climate change vulnerability assessment of the Ontario Great Lakes Basin (top to bottom): spring peeper (*Pseudacris crucifer*); white spruce (*Picea glauca)*. Credit: Sam Brinker; wood duck (*Aix sponsa*). Credit: Colin Jones.

Contents


Little Trout Bay, Lake Superior.
Photo: Sam Brinker

1 Introduction

Climate change represents a pervasive stress to Ontario's natural resources and one of the greatest emerging environmental and societal issues in the Great Lakes Basin (McDermid et al. 2015). Mounting evidence shows that increases in greenhouse gases during the last 50 years have contributed greatly to warming of the Earth's climate (IPCC 2007) and changes in many organisms' behaviour (e.g., van Herk et al. 2002, Root et al. 2003, Hickling et al. 2005, Hitch and Leberg 2007, Lenoir et al. 2008, Garroway et al. 2010, DeLeon et al. 2011, Ellwood et al. 2013, Klaus and Lougheed 2013). Rapid, dramatic changes in the Earth's climate are expected over the next century following continued increases in greenhouse gases (IPCC 2007; Figure 1).

Climate change will influence the distribution, composition, and structure of Ontario's ecosystems and may impair ecosystem function and threaten the survival of certain species. Populations have 2 survival options, they can remain in situ and tolerate the new conditions, or they can move to track their climatic niches (e.g., Graae et al. 2018). Thus we can expect shifting distributions through dispersal processes, with more species expanding their ranges north while others will persist through adaptation or decline. As the provincial agency responsible for managing natural resources, the Ministry of Natural Resources and Forestry (MNRF) has an important role in helping the Province identify the potential effects of a changing climate on species and ecosystems and continue to fulfill its sustainable natural resource management mandate.

Figure 1. In Ontario, climate change projections suggest average annual air temperature will increase, but by how much is unclear. More heat in the atmosphere will increase variability in precipitation and wind patterns, changing the frequency and size of extreme weather events such as ice storms, heavy rains, and windstorms (McDermid et al. 2015). Photo: Sam Brinker.

Over the next several decades, temperatures in Ontario are projected to increase anywhere from 1.5 to 7 °C depending on the climate scenario and model used to derive estimates (McKenney et al. 2010), leading to warmer winters with longer frost-free periods and warmer summers with longer growing seasons. Annual precipitation in the Great Lakes Basin is projected to increase by 20%, with increases in spring and winter rain and decreases in summer rain and winter snow (McDermid et al. 2015; figures 1, 2). Predicted hydrological changes include a decline in water levels due to warming air temperatures, increased evaporation and evapotranspiration, and seasonal changes in precipitation patterns (Lofgren et al. 2002).

Most climate change models have predicted lower Great Lakes water levels due mainly to higher summer air temperatures, reduced ice cover, and increased evaporation (Mortsch et al. 2000, Kling et al. 2003, Jensen et al. 2007). Droughts are predicted to increase in frequency and extent, while rain events will become more sporadic and extreme (Kling et al. 2003). Surface water temperatures are expected to increase from 0.9 to 6.7 °C. Meanwhile, lake ice cover is expected to decrease in duration, thickness, and extent. For example, over the past 40 years, the maximum amount of ice forming on the Great Lakes each year has declined 17 to 40% (Karl et al. 2009). These changes will affect species and ecosystems, but projected extreme events or seasonal changes could cause even greater effects.

How might species respond to such changes? Which species are most vulnerable? Which species might increase in abundance? Indeed, many species distributions are already shifting in response to climate change. Chen et al. (2011) estimated that globally, terrestrial species have shifted to higher latitudes at a median rate of 16.9 km per decade, a rate 2 to 3 times faster than previously recorded. While mobile species may be able to respond and adapt to rapid change, others may not. Especially vulnerable are those in fragmented landscapes, such as in the southern part of the Ontario Great Lakes Basin. Understanding which traits will make some species more vulnerable than others is crucial to developing adaptation strategies and building resilience.

An early step in climate change adaptation is to assess species of interest for their climate change vulnerability (Lawler et al. 2010, Cross et al. 2012). *Vulnerability* is the degree to which a species is susceptible to and unable to cope with adverse effects of climate change. It is a function of the character, magnitude, and rate of change and variation to which a species is exposed, its sensitivity, and its ability to adapt (IPCC 2007; see glossary in Appendix A).

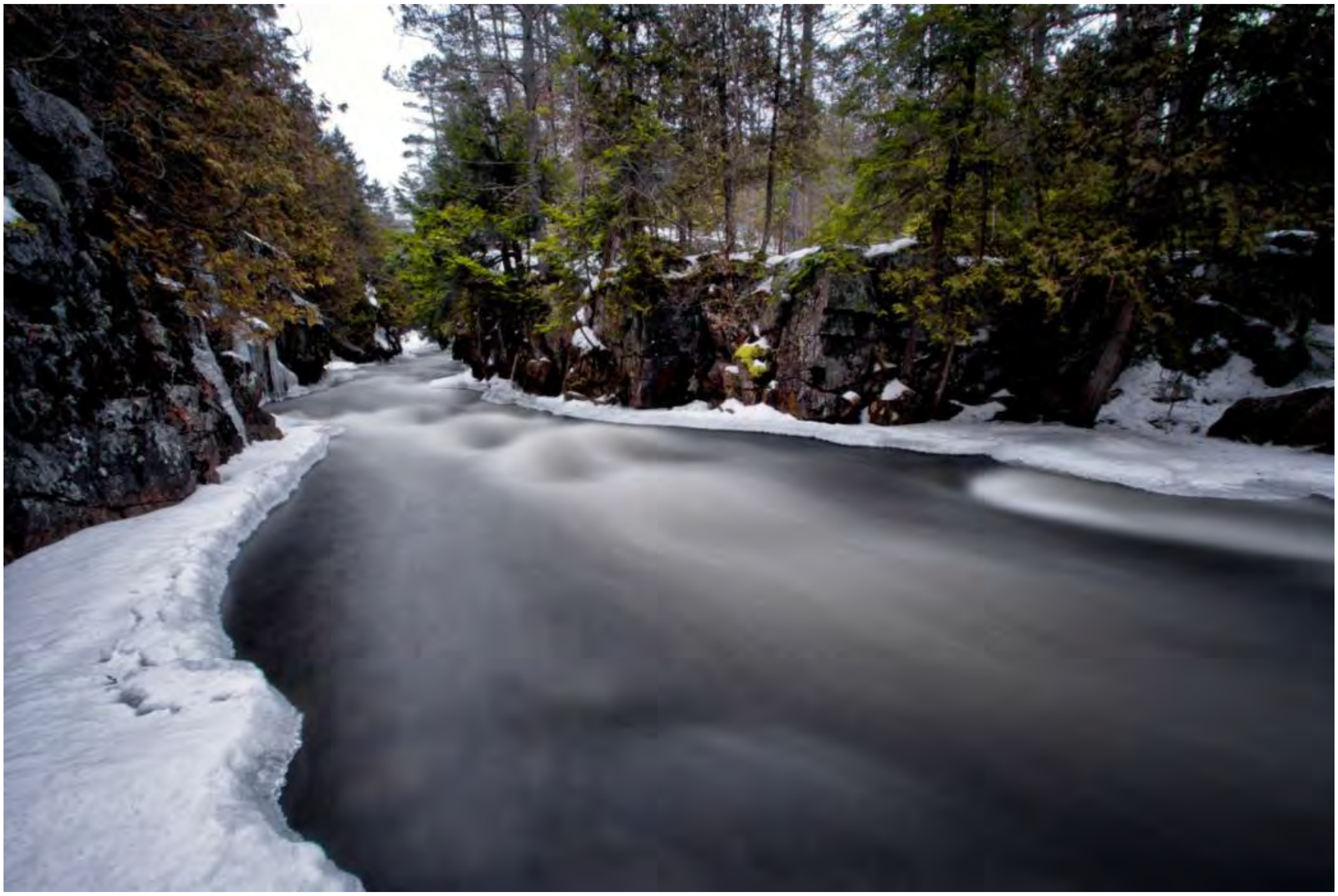

Figure 2. The average number of days with snow on the ground and ice over water bodies is projected to decrease in the Ontario Great Lakes Basin as the climate changes (Crowe River). Photo: Sam Brinker.

Various methods can be used to determine species or habitat vulnerability to climate change. Many approaches are being tested, with vulnerability indices proving to be rapid, effective, and efficient. These indices allow the user to evaluate a combination of traits associated with a species' exposure, sensitivity, and ability to adapt (Williams et al. 2008, Rowland et al. 2011, Foden et al. 2013). Trait-based approaches usually incorporate biological characteristics as predictors of extinction risk due to climate change, combined with estimates of historic and future modelled exposure to temperature and precipitation changes (Young et al. 2012).

We chose the NatureServe Climate Change Vulnerability Index (CCVI; Canadian v.3.0; Young and Hammerson 2015), because it provides a rapid, expert-informed means to estimate species' relative vulnerability to climate change. It combines data on natural history, distribution, and management with downscaled climate predictions for a chosen geographic area. The user can address all biodiversity elements (except marine species), and this tool has been used by many agencies and institutions with most major taxa (e.g., Byers and Norris 2011, Dubois et al. 2011, Furedi et al. 2011, Schlesinger et al. 2011, Brinker and Jones 2012, Hoving et al. 2013, Shank et al. 2014, Sneddon and Hammerson 2014, Still et al. 2015, Tuberville et al. 2015).

The CCVI's scoring reflects factors known to affect climate change vulnerability and places species into broad vulnerability categories (Young and Hammerson 2015). It can help resource managers to screen large numbers of species from diverse taxonomic groups and identify those most vulnerable and the factors leading to their vulnerability (Young and Hammerson 2015). It incorporates 16 life history traits likely to influence climate sensitivity and adaptive capacity (e.g., physiological attributes, dispersal mechanisms, pollinator specificity, and geologic substrate fidelity; Figure 3), as well as climate exposure information.

Figure 3. High substrate fidelity is one of several life history traits incorporated into the NatureServe Climate Change Vulnerability Index that influence a species' vulnerability to climate change. In the Ontario Great Lakes Basin, alpine copper moss (*Mielichhoferia mielichhoferiana*) is a species restricted to near-vertical rock faces with high iron levels and reduced sulphur. Photo: Sam Brinker.

Figure 4. The Great Lakes Basin contains the largest freshwater ecosystem in the world. Pictured here is one of more than 3,700 coastal wetlands found in the Georgian Bay region (Fracz and Chow-Fraser 2013). Photo: Sam Brinker.

2 Methods

2.1 Assessment area

The Great Lakes Basin contains the watersheds or sub-basins of the 5 Great Lakes: Superior, Huron, Michigan, Erie, and Ontario, an area of roughly 1,200 km from west to east that covers more than 765,000 km², including parts of 8 U.S. states and 2 Canadian provinces. It is the largest freshwater ecosystem in the world, storing 20% of the world's supply of surface freshwater (Figure 4), supporting a growing human population and one of the largest industrial complexes in the world (TNC 2000). The Ontario Great Lakes Basin (Figure 5) spans an area of 230,000 km², extending from its southern limits at Lake Erie (42°N) north to its head waters, which originate north of Lake Nipigon (50°N). It includes portions of all Great Lakes except Lake Michigan. While technically not part of the Great Lakes Basin, the St. Lawrence watershed up to the Trois-Rivières dam in Québec is sometimes included since lake levels directly affect it (IJC 2016); it was therefore included in our assessment. Drainage flows from north to south and west to east from Lake Nipigon into lakes Superior, Huron, Erie, and Ontario to the St. Lawrence River.

The land of the Ontario Great Lakes Basin is about one-third of the province, part of the Ontario Shield and Mixedwood Plains terrestrial ecozones (Crins et al. 2009). Because of the large size and unique position of the watershed, climate, soils and topography vary across the basin. Northern streams and inland lakes flow through conifer or mixed forests over relatively thin, acidic soils underlain by Precambrian granite bedrock of the Canadian Shield (Magnuson et al. 1997, Crins et al. 2009). Southern inland lakes and streams flow through deciduous or mixed forests, agricultural lands, as well as urban areas and are underlain by till,

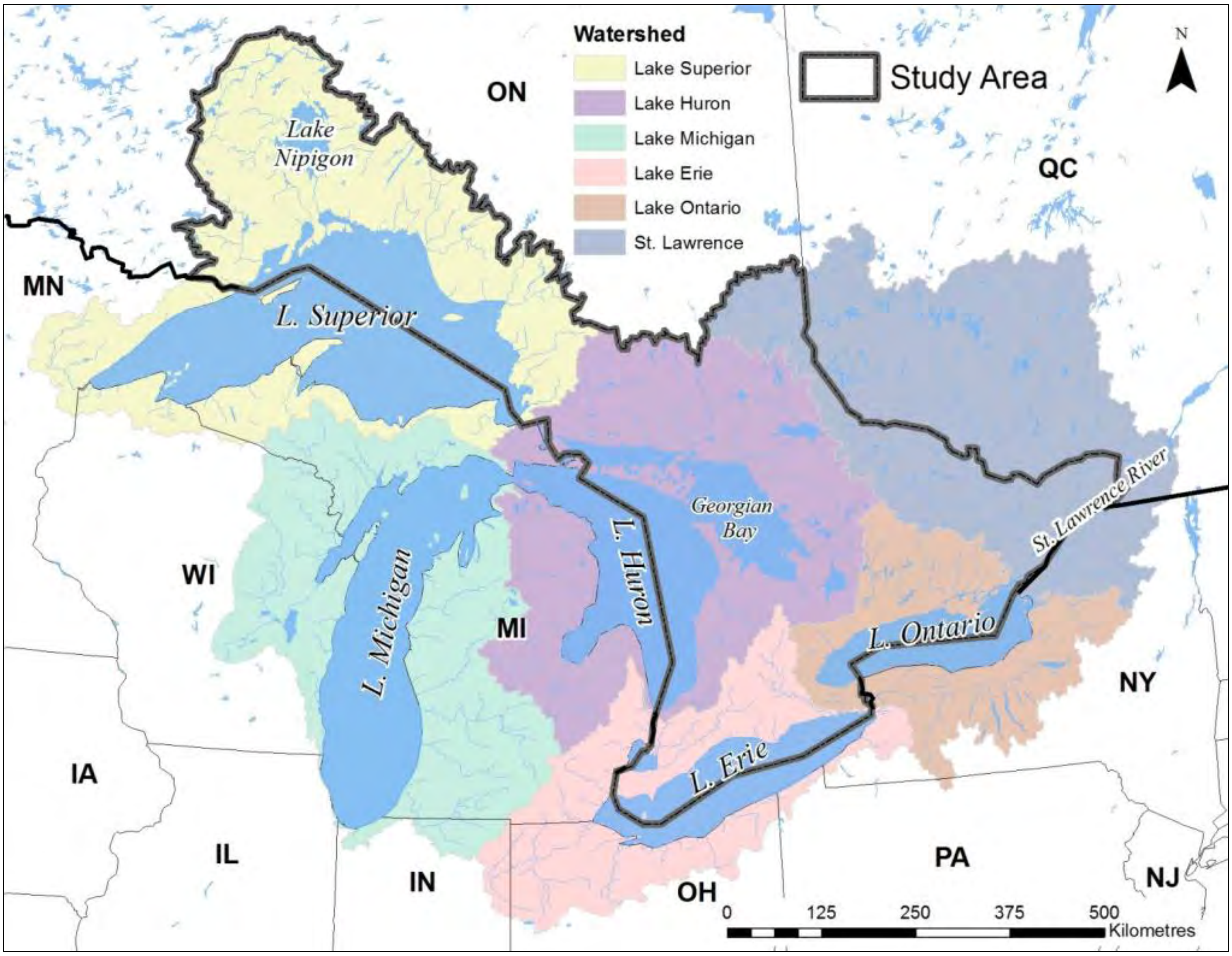

Figure 5. The Great Lakes Basin and associated watersheds (shaded). The Ontario Great Lakes Basin, the area of an assessment on species' vulnerability to climate change, is outlined in black.

glaciolacustrine, and glaciofluvial deposits that are mostly over limestone, sandstone, and shale formations.

Elevation ranges from about 74 m in lowland areas to about 679 m on the shield. Mean annual air temperature ranges from 9.1 °C in the south to 0.5 °C in the north. Land use activities include urban development, industry (including power generation on both land and water), agriculture, transportation, recreation (e.g., fishing, hunting), road development, and others.

The Great Lakes Basin has the greatest diversity of species in Canada and is one of the most diverse ecoregions in North America (Comer et al. 2003). It has the world's largest collection of freshwater coastal dunes (Government of Ontario 2012), and roughly three-quarters of Great Lakes alvars are in Ontario (Brownell and Riley 2000). Biologically, it includes species with broad floristic affinities including Carolinian, boreal, Arctic, Atlantic Coastal Plain, Western Cordilleran, with some species and subspecies that are endemic to the Great Lakes region.

2.2 The Climate Change Vulnerability Index (CCVI)

To assess vulnerability to climate change, we used the NatureServe Climate Change Vulnerability Index (Canadian Version v.3.0, Young and Hammerson 2015). It incorporates exposure-weighted scoring of multiple factors that could affect species' vulnerability into a Microsoft Excel workbook. In the spreadsheet, users enter numerical and categorical responses to questions about risk factors related to species exposure, climate change sensitivity, and adaptive capacity. An index score is calculated from the entries on exposure and sensitivity, and converted to a categorical vulnerability score. The focus is on species' intrinsic traits and physiological characteristics rather than geographic range size or anthropogenic threats, allowing comparisons among species with differing conservation statuses or range sizes. Shifts in competitive, predator-prey, or host-parasite interactions are likely to be very important, and the CCVI does incorporate several variables that assess interspecific interactions pertaining to sensitivity to pathogens, predators, herbivores, competition from native or non-native species, and other types of parasitism or commensalism (Young and Hammerson 2015).

For our assessment, modelled climate data were used to determine projected changes in temperature and moisture throughout each species' current range in the Ontario Great Lakes Basin by the 2050s, generating an exposure score (Figure 6). This time horizon is far enough in the future for significant changes to have occurred, but before temperature projections from different emissions scenarios and global circulation models diverge substantially (Meehl et al. 2007). Then sensitivity factors were evaluated based on historical climate analyses, species distribution mapping, literature review, and expert opinion to determine a sensitivity score, where *sensitivity* is how closely a species is linked to particular microclimates and ecological conditions that climate change might affect, as well as the species' ability to adapt to change. Sensitivity was assessed using 2 types of variables (Table 1):

1. Indirect (landscape climate change effects in a species' range):
   a) Sea level rise (not applicable to the Ontario Great Lakes Basin so always scored neutral or having no effect)
   b) Distribution relative to barriers (natural and anthropogenic)
   c) Predicted effects of land use changes due to human response to climate change (e.g., wind farm development, tree plantations for carbon sinks, solar farms)
2. Species-specific sensitivity and adaptive capacity factors: Dispersal ability; restriction to rare habitats or geologic features, dependence on ice or snow cover, dietary versatility, reliance on particular pollinators or host-parasite relationships; genetic diversity

We also factored documented or modelled responses to climate change into the assessment where possible. Based on analysis of climate data, species distributions, relevant literature, and expert opinion, we scored each factor according to its contribution to each species' vulnerability.

Vulnerability scores fall into one of 4 categories: neutral, somewhat increased vulnerability, increased vulnerability, and greatly increased vulnerability. If a factor was unknown, it was scored as such. Where uncertainty about a classification existed, we assigned a score range across 2 categories as advised by Young and Hammerson (2015). Information is often insufficient to score all factors, so the index provides some flexibility, requiring at least 14 out of the 20 sensitivity and indirect exposure factors to generate a vulnerability score.

The combined exposure and sensitivity scores are used to generate an overall vulnerability score. We first performed the calculations using the NatureServe CCVI Canadian v.2.01 (Young et al. 2010) and then re-analyzed each species using v.3.0 (Young and Hammerson 2015) after its release. The new release has several improvements including a means to assess climate effects in overwintering areas of migratory species when they are not present within the basin, 2 more interspecific factors (sensitivity to pathogens/natural enemies and sensitivity to competition from native/non-native species), and a new factor that considers plant reproductive systems. An important caveat is this tool does not allow assessment of conservation threats unrelated to climate change. Rather the results are intended to be used in conjunction with other conservation status assessments.

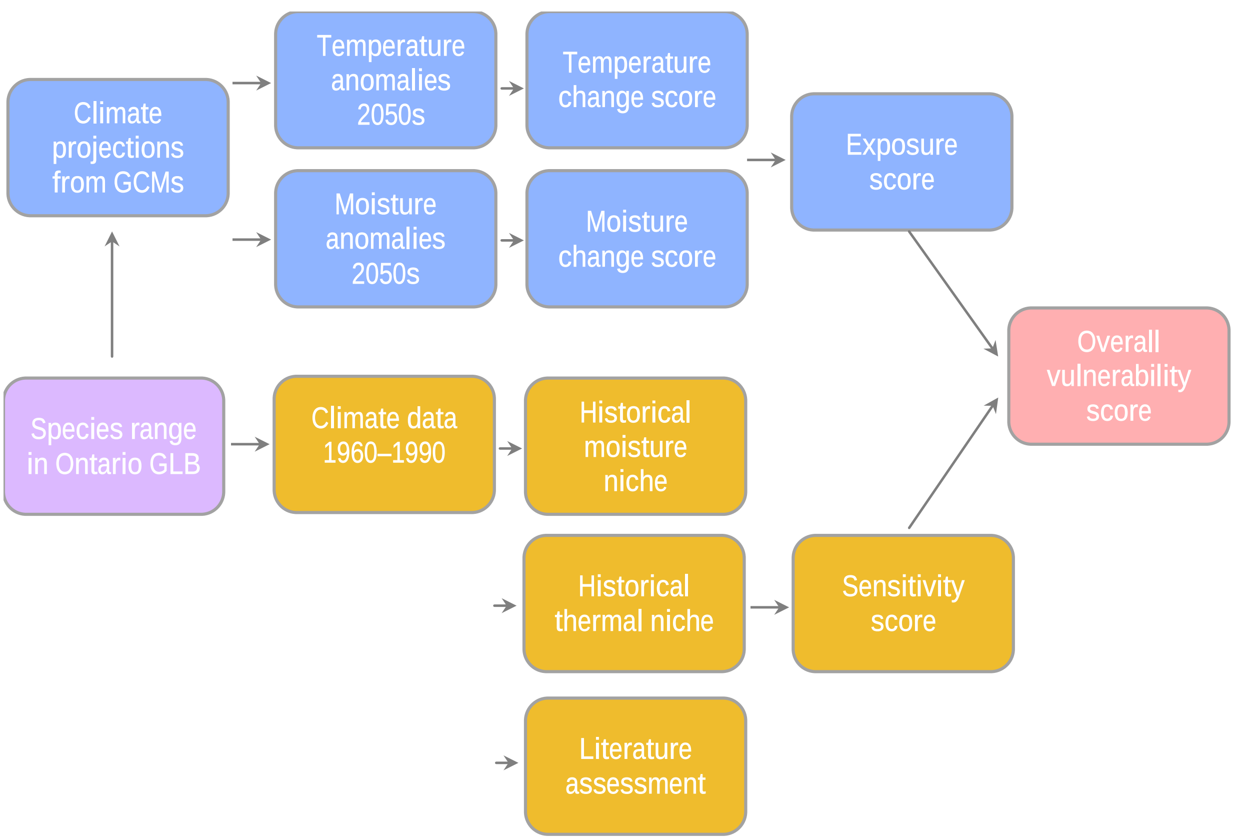

Figure 6. This flow chart (modified from Shank and Nixon 2014) shows the factors used to calculate vulnerability scores using NatureServe's Climate Change Vulnerability Index to assess climate change vulnerability in Ontario Great Lakes Basin species.

Table 1. Variables used to assess climate change vulnerability of Great Lakes Basin species (following Young and Hammerson 2015).

Direct exposure to local projected climate change

- Per cent of species range in 5 categories of **increasing temperature**
- Per cent of species range in 6 categories of **changing moisture regime**
- Per cent of species **migratory range** in 4 categories of **climate change exposure** (for migratory birds on their over-wintering range)

Indirect exposure to climate change

- Exposure to **sea level rise (not applicable to the Ontario Great Lakes Basin so scored as neutral)**
- Distribution relative to **natural barriers**
- Distribution relative to anthropogenic **barriers**
- Predicted impact of **land use changes resulting from human responses** to climate change

Factors that influence **sensitivity** and climate change adaptive capacity

- **Dispersal and movements**
- Predicted **sensitivity to changes in temperature**
- Predicted **sensitivity to changes in precipitation, hydrology, or moisture regime**
- Dependence on a **specific disturbance regime** likely to be affected by climate change
- Dependence on **ice, ice-edge, permafrost or snow-cover habitats**
- Restriction to **uncommon landscape/geological features or derivatives**
- Dependence on **other species to generate habitat**
- **Dietary versatility** (animals only)
- **Pollinator versatility** (plants only)
- Dependence on **other species for propagule dispersal**
- Sensitivity to **pathogens or natural enemies**
- Sensitivity to **competition** from native or **non-native species** (benefitting from climate change)
- Other **interspecific interactions not covered**
- Measured **genetic variation**
- Occurrence of **bottlenecks** in recent evolutionary history
- **Reprodutive system** (plants only)
- **Phenological response** to changing seasonal temperature and precipitation dynamics

Documented or **modelled response** to climate change

- **Documented response** to recent climate change
- Modelled **future (2050) change in population** or **range size**
- **Overlap** of modelled future (2050) range with current range
- Occurrence of **protected areas in modelled future (2050) distribution**

Other intrinsic factors

- **Taxonomic group**
- Obligation to **cave** or **groundwater aquatic habitats**
- **Provincial conservation status** rank (Srank)
- **Global conservation status** rank (Grank)

2.3 Climate data inputs

Recent historic climate data

The CCVI requires climate inputs from both recent historical records (for our assessment 1960–1990) and near-future time periods (for our assessment 2041–2071, referred to as the 2050s). Recent historical records for differences in seasonal temperature and spatial precipitation are used as a proxy for the breadth of species' evolved climate niches (Figure 7). The more a species has been exposed to large variations in temperature and precipitation, the more likely it could adapt to future variation.

Seasonal differences between winter minimum and summer maximum temperatures are highly correlated with latitude. The Lake Superior basin in the northern portion of the Great Lakes basin has historically received the highest seasonal differences in temperature oscillations (Figure 7A). Areas with the smallest differences occur around the near shore areas of the lower three Great Lakes, especially the leeward side of Lake Huron and the north shore of Lake Erie (Figure 7A) which are moderated most by the Great Lakes. Highest historic annual rainfall totals for the Ontario Great Lakes basin occur on the leeward sides of Lakes Superior, Huron, and Georgian Bay (Figure 7B), especially in the Sault Ste. Marie, Parry Sound and Dundalk Highlands regions. Meanwhile, the northwestern portion of the study area west of Thunder Bay and areas surrounding Lake Nipigon have received the lowest relative historic annual rainfall totals.

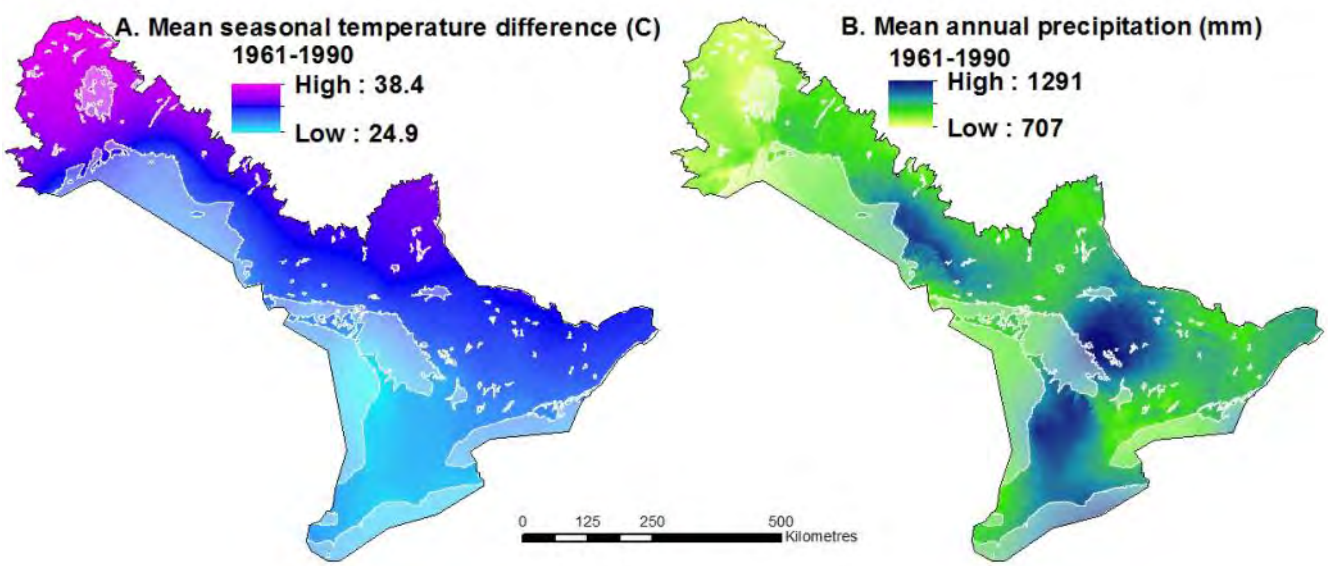

Figure 7. Historical climate data (1960–1990) used as inputs into the Climate Change Vulnerability Index to assess Ontario Great Lakes Basin species: A) past exposure to temperature variation represented as mean difference between winter minimum and summer maximum temperatures, from light blue (24.9 °C) through to purple (38.4 °C), and B) past exposure to precipitation represented as mean annual precipitation (mm), from yellow (707 mm) through green to blue (1291 mm).

Projected future climate data

Future climate exposure is the extent to which a species will experience a departure from recent historic temperature and available moisture by the 2050s, an accepted period for projections according to IPCC reports (e.g., IPCC 2007). Future climate projections for the 2050s were downscaled using AdaptWest[1] at 1 km resolution from IPCC Fifth Assessment Report representative concentration pathways 4.5 projections, averaged from 15 general circulations models (GCMs) to be consistent with the original CCVI, which was based on a mid-range scenario (Young et al. 2010). The data depart (delta) from the 1961–1990 mean for the years 2041–2070 (2050s). Due to the number of species we assessed, we selected only 1 RCP climate scenario.

While the magnitude of warming varies spatially, the trend shows warming is increasing from south to north, with models projecting the greatest departures from recent historic temperatures in the northern half of the Ontario Great Lakes Basin, where future temperatures are projected to rise by over 3 °C by the 2050s (Figure 8A). Areas in the extreme southwest are projected to depart somewhat less from recent historic temperatures, by about 2.7 °C by the 2050s. Many parts of the basin are projected to have net drying over the next 50 years, even where precipitation is projected to increase (Brooks 2009). The CCVI incorporates the Hamon AET:PET moisture metric (Hamon 1961) to assess future drying. It integrates

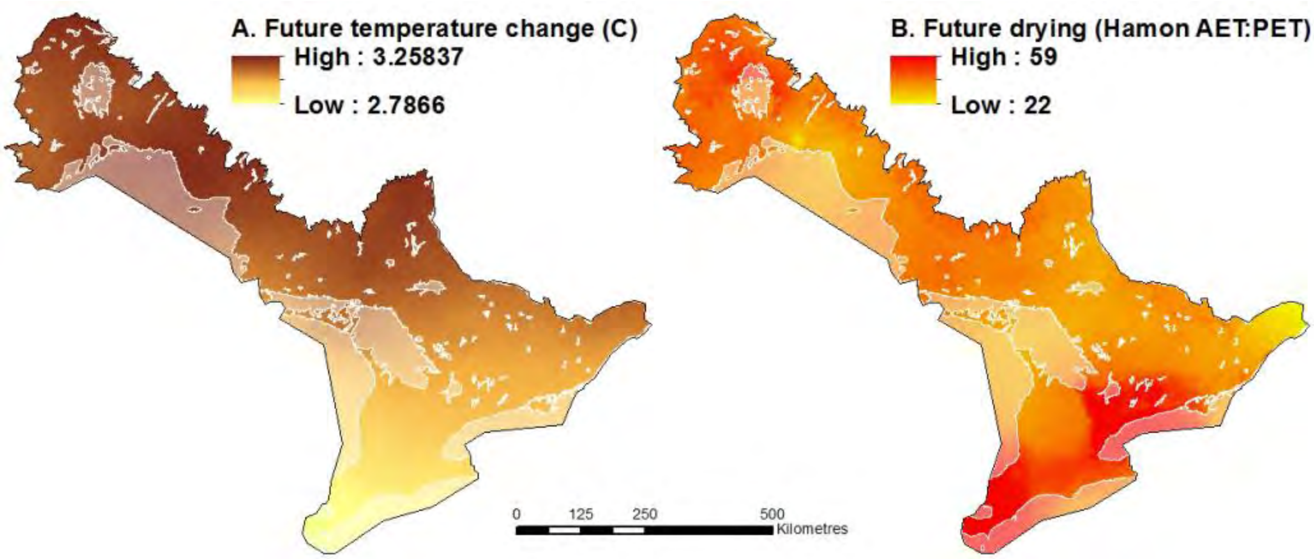

Figure 8. Differences between historical climate data (1961–1990) and projected climate for the 2050s (Ensemble) for Ontario's Great Lakes Basin: A) projected mean annual temperature change, from yellow (2.7°C) to maroon (3.25°C), and B) projected change in moisture availability using the Hamon (1961) actual:potential evapotranspiration moisture metric from yellow (least drying) to red (most drying).

---

[1] AdaptWest is a spatial database and synthesis of methods for conservation planning aimed at enhancing resilience and adaptation potential of natural systems under climate change. https://adaptwest.databasin.org/

temperature and precipitation through a ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET), with consideration of total daylight hours and saturated vapour pressure. It does not include components of moisture retention found in certain habitats such as snowpack, water holding capacity of different substrates, and different vegetation types.

As shown in Figure 8B, the entire Ontario Great Lakes Basin is projected to see increased net drying. Areas expected to have the most drying due to warming air temperatures, seasonal precipitation shifts, and increased evaporation and evapotranspiration are in the southern (north shores of lakes Erie and Ontario) and northwestern (Lake Nipigon) parts of the basin (Figure 8B). Areas along the western part of the north shore of Lake Superior, Georgian Bay, and eastern Ontario are expected to have the least net drying (Figure 8B).

2.4 Vulnerability scores

The index allows the user to calculate an index score and a measure of confidence. Since some species may not be inherently sensitive to climate change or are sensitive but not expected to have significant exposure risk, this tool weights the numerical scores for the sensitivity factors by the magnitude of projected temperature and moisture change across the assessment area. The index scores provide a relative measure of climate change vulnerability that helps separate species with many risk factors from those with fewer. The 5 possible outcomes are: extremely vulnerable, highly vulnerable, moderately vulnerable, less vulnerable, and insufficient evidence (Figure 9).

The index also allows the user to calculate a measure of confidence in species information. Uncertainty in available data and/or limits to current knowledge about biological traits is factored in by scoring multiple categories for a single sensitivity factor. Confidence is measured by summarizing the results of a Monte Carlo simulation for 1,000 iterations using 1 of each of the multiple sensitivity factor scores (Young and Hammerson 2015). Relative confidence is represented by probability statements for each score: very high implies >90%, high=80–90%, moderate=60–80%, and low=<60% certainty.

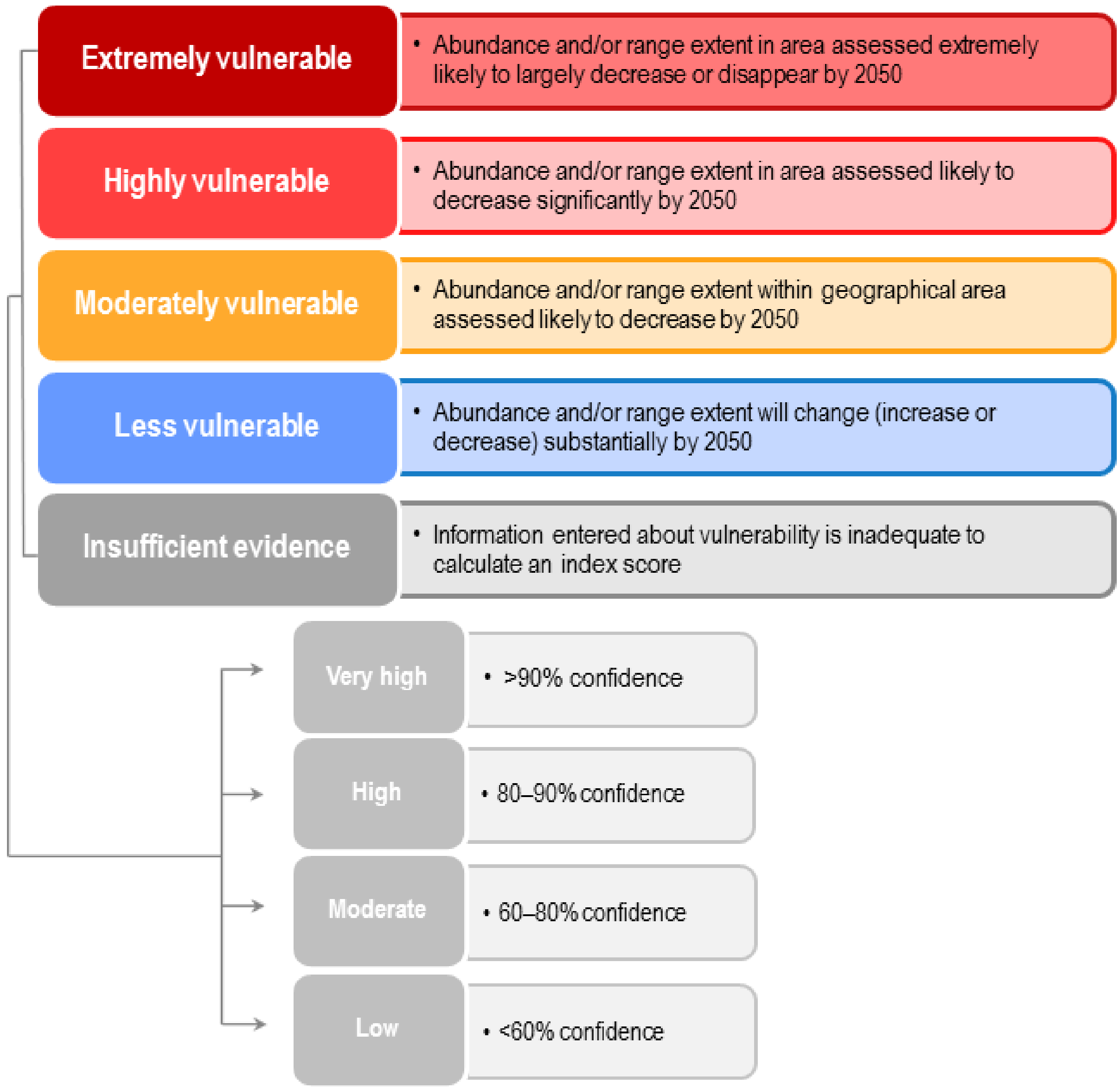

Figure 9. Climate Change Vulnerability Index scores and confidence levels (Young and Hammerson 2015).

2.5 Species selection

The large number of species occurring in the Ontario Great Lakes basin, along with available time, funds, and access to expert input precluded an assessment of all, or even a significant portion of them. Our goal was to determine the vulnerability of a representative subset whose ranges covered some part of the basin. Results could then be applied to species not assessed. To select a representative group of focal species, we considered these factors:

1. Suspected of being directly or indirectly sensitive to climate change based on life history traits

2. Is a habitat specialist or keystone species
3. Is of conservation concern (globally or provincially) or is a federally or provincially listed species at risk
4. Is at southern or northern range limits or endemic to the Great Lakes Basin
5. Had sufficient distributional and ecological data to complete an assessment

We also tried to cover off a range of taxonomic groups: amphibians, birds, bryophytes, fishes, insects and spiders, lichens, molluscs, reptiles, and vascular plants. Often our decision rested on whether enough distribution and ecological data was available. Species easier to identify in the field (e.g., many mammals, vascular plants), more commonly sought by citizen scientists (e.g., amphibians, reptiles, birds, dragonflies, butterflies), or having robust monitoring programs (e.g., some species at risk) tend to have more reliable distribution data and were evaluated more so than groups lacking adequate distributional data such as invertebrates, bryophytes and lichens.

Location data and distribution maps

Several sources were used to develop species distribution maps. Location data for provincially tracked species came from MNRF's Natural Heritage Information Centre species element occurrence data (NHIC 2015). An *element occurrence* is an area of land and/or water in which a species or ecosystem is or was present. It often corresponds with the local population but may be a portion of a population (e.g., long distance dispersers) or a group of nearby populations (metapopulation). Element occurrences include species that have a provincial conservation status rank of extirpated, historic, critically imperilled, imperilled, or vulnerable or are partially tracked (see Glossary for definitions). We omitted extirpated element occurrences since we did not know whether suitable habitat was still present.

Partially tracked species typically have disjunct populations in the basin away from their main range, separated by hundreds of kilometres of unsuitable habitat but may be locally common in the Far North near Hudson Bay and James Bay. These local populations have different natural and anthropogenic threats from those of northern populations and are therefore of conservation concern only in the Ontario Great Lakes Basin (e.g., Brinker 2017; Figure 10).

Other important data sources:

- Atlas of the Breeding Birds of Ontario (Cadman et al. 2007)
- Ontario Reptile and Amphibian Atlas (Ontario Nature 2016)
- Ontario Butterfly Atlas (Macnaughton et al. 2016)
- Ontario Odonata Atlas Database (NHIC 2016)
- Atlas of the Mammals of Ontario (Dobbyn 1994)
- Consortium of North American Lichen Herbaria (CNALH 2016)
- Consortium of North American Bryophyte Herbaria (CNABH 2016)
- Digital representation of North American tree range maps (USGS 1999)

Since distribution maps for many assessed species were not available or available only as generalized range polygons, they often included large areas of unoccupied and potentially unsuitable habitat that may not represent species' climatic needs and tolerances. Therefore location data for each species was mapped using ArcMap 10.1 and overlain with a 10x10 km square grid covering the assessment area. Each square that overlapped location data was deemed occupied, and for each species, the occupied squares were converted to a raster file to generate temperature and moisture exposure values.

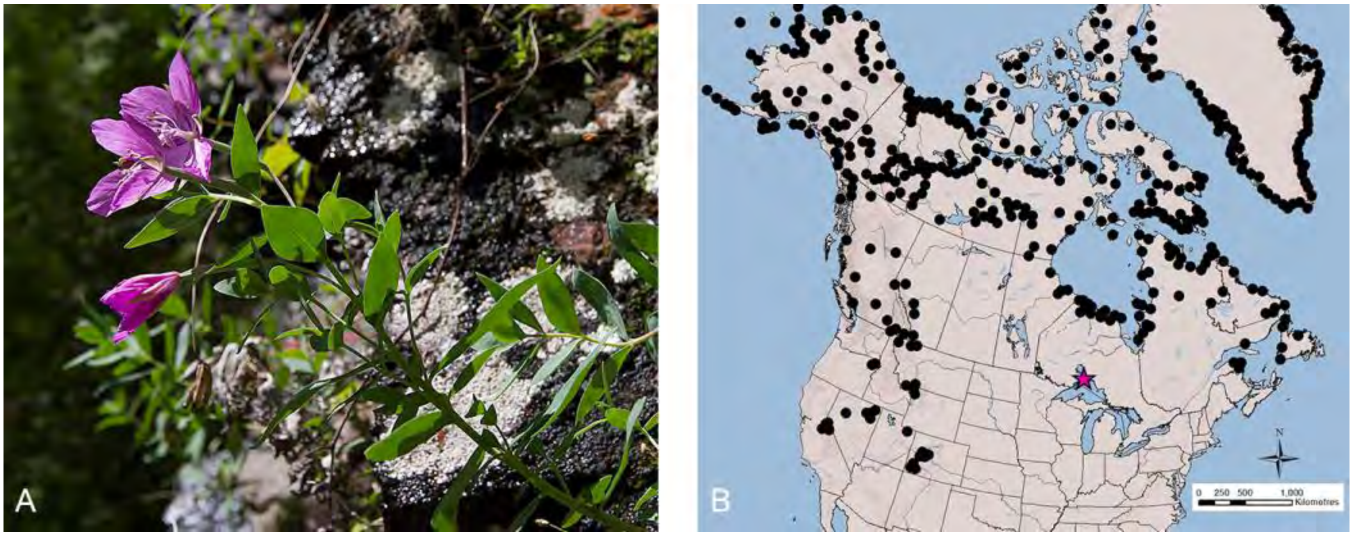

Figure 10. A) River beauty (*Chamaenerion latifolium*) is an example of an arctic-alpine plant species that is of conservation concern only in the Ontario Great Lakes Basin (partially tracked) where a single population is known from cliff habitat, but not of conservation concern in the Far North where it is a common tundra species along gravel bars and alluvial floodplains of rivers draining into Hudson Bay. B) The North American distribution of river beauty denoted with black dots; the purple star showing the disjunct Great Lakes Basin population (modified from Brinker 2017). A subset of partially tracked species was included in this assessment of climate change vulnerability in the Ontario Great Lakes Basin.

3 Results and discussion

Of the 280 species assessed, 175 were found to be vulnerable (extremely, highly, or moderately) to climate change (Figure 11): 11 were extremely vulnerable, 49 were highly vulnerable, and 115 were moderately vulnerable. The remaining 105 species were found to be less vulnerable. Appendix B lists all climate change vulnerability index scores, confidence levels, and conservation status ranks and basin presence for each assessed species.

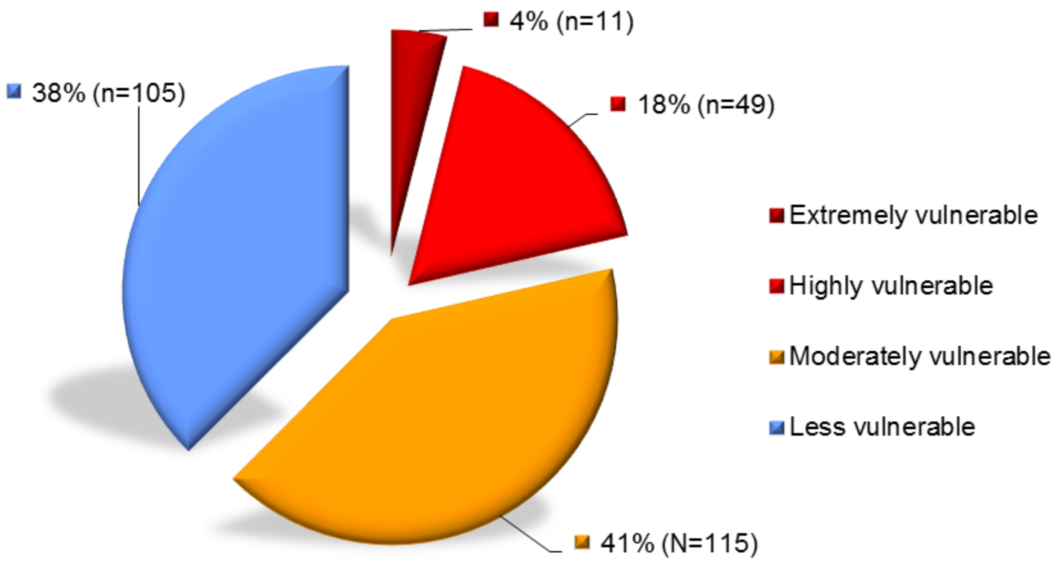

Figure 11. Per cent (and number) of species in each climate change vulnerability category in an assessment of Ontario Great Lakes Basin species.

Most vulnerable species

Table 2 lists the 11 extremely vulnerable species, 5 of which are arctic-alpine plants that are disjunct in the Great Lakes region away from their main range much farther north. In the basin, they are restricted to cool rocky coastal areas along Lake Superior as well as isolated inland canyons, cliffs, and talus slopes. Populations are often separated by natural barriers, either expanses of open water or closed boreal forest, limiting successful dispersal. Such peripheral populations of arctic-alpine plants have been highlighted as particularly vulnerable to warming climates (Lesica and McCune 2004, Klanderud 2008, Gibson et al. 2009), and the loss of any could be a reduction in genetic diversity (Hampe and Petit 2005, Hamilton and Eckert 2007). These species and their associated habitat are expected to be among the most vulnerable to climate change due to projected warming temperatures and declines in mean annual snowfall in the Great Lakes Basin.

Both shortjaw cisco (*Coregonus zenithicus*) and redside dace (*Clinostomus elongatus*) are aquatic species that prefer cold water (deepwater columns in lakes and spring-fed cool water streams, respectively). Increasing temperatures may destabilize populations of both by altering predator-prey relationships and reducing spawning site quality. Other species that appear extremely vulnerable — such as dusted skipper (*Atrytonopsis hianna*) and bent spikerush (*Eleocharis geniculata*) — often occur in small populations separated from other potentially suitable habitat by large expanses of anthropogenic barriers (farmland, urban areas) and are restricted to rare habitat types.

Table 2. Species found to be extremely vulnerable to climate change in an assessment of the Ontario Great Lakes Basin.

Taxonomic group	Scientific name[1]	Common name
Fish	*Clinostomus elongatus*	Redside dace
Fish	*Coregonus zenithicus*	Shortjaw cisco
Insect	*Atrytonopsis hianna*	Dusted skipper
Mollusc	*Simpsonaias ambigua*	Salamander mussel
Vascular plant	*Chamaenerion latifolium*	River beauty
Vascular plant	*Dryas drummondii*	Yellow mountain-avens
Vascular plant	*Eleocharis geniculata*	Bent spikerush
Vascular plant	*Oplopanax horridus*	Devil's club
Vascular plant	*Pyrola grandiflora*	Arctic pyrola
Vascular plant	*Saxifraga oppositifolia*	Purple mountain saxifrage
Vascular plant	*Silene acaulis*	Moss campion

[1]For conservation ranks and basin presence, see Appendix B.

Table 3 lists the 49 species found to be highly vulnerable. Many of the wildlife species are entirely aquatic or amphibious and tend to be poor dispersers with small, isolated populations. Eight of the highly vulnerable species are considered globally rare, and some, such as Lake Huron grasshopper (*Trimerotropis huroniana*) and lakeside daisy (*Tetraneuris herbacea*), are found nowhere outside the Great Lakes Basin. Five of the vascular plant species were orchids, which often need both specific insect pollinators (e.g., Bowles 1991) and mycorrhizal fungi for seedling germination and overall fitness (e.g., McCormick et al. 2012, Rock-Blake et al. 2017, Fay et al. 2018).

The boreal population of caribou (*Rangifer tarandus;* Figure 12) was the only mammal found to be highly vulnerable. Climate change is expected to affect caribou by reducing habitat suitability and forage availability. Caribou depend on mature to old growth boreal forest with sufficient lichen abundance and appropriate lichen communities that develop in old forests for forage, and climate change will likely result in more fires and drier soils, reducing the amount of appropriate arboreal lichen winter forage as forest stands change with shortened fire cycles. As moose and deer invade preferred caribou habitat, predators and disease will follow, putting caribou at further risk. Also, predicted increases in insect outbreaks such as spruce budworm (*Choristoneura fumiferana*) resulting from climate change will also affect caribou habitat, e.g., by further reducing the extent of mature forest cover (COSEWIC 2002).

Table 3. Species found to be highly vulnerable to climate change in an assessment of the Ontario Great Lakes Basin (pop. = population).

Taxonomic group	Scientific name*	Common name
Amphibian	*Anaxyrus fowleri*	Fowler's toad
Amphibian	*Desmognathus fuscus*	Northern dusky salamander
Amphibian	*Desmognathus ochrophaeus*	Allegheny mountain dusky salamander
Bird	*Charadrius melodus*	Piping plover
Bird	*Parkesia motacilla*	Louisiana waterthrush
Bryophyte	*Aulacomnium acuminatum*	Acutetip groove moss
Bryophyte	*Bryoandersonia illecebra*	Spoon-leaved moss
Bryophyte	*Mielichhoferia mielichhoferiana*	Alpine copper moss
Bryophyte	*Tortula porteri*	Porter's screw moss
Fish	*Acipenser fulvescens* (pops. 1 and 2)	Lake sturgeon (pops. 1 and 2)
Fish	*Ammocrypta pellucida*	Eastern sand darter
Fish	*Ichthyomyzon fossor*	Northern brook lamprey
Fish	*Lepisosteus oculatus*	Spotted gar
Fish	*Moxostoma duquesnei*	Black redhorse
Fish	*Percina copelandi*	Channel darter
Insect/spider	*Callophrys lanoraieensis*	Bog elfin
Insect/spider	*Trimerotropis huroniana*	Lake Huron grasshopper
Lichen	*Arthrorhaphis alpina*	Alpine dot lichen
Lichen	*Bryoria pikei*	Pike's horsehair lichen
Lichen	*Flavocetraria nivalis*	Crinkled snow lichen
Lichen	*Pseudocyphellaria holarctica*	Yellow specklebelly lichen
Lichen	*Sticta beauvoisii*	Fingered moon lichen
Lichen	*Usnea longissima*	Methuselah's beard lichen
Mammal	*Rangifer tarandus*	Caribou (boreal population)
Mollusc	*Epioblasma torulosa rangiana*	Northern riffleshell
Mollusc	*Epioblasma triquetra*	Snuffbox
Mollusc	*Villosa fabalis*	Rayed bean

Taxonomic group	Scientific name*	Common name
Reptile	*Plestiodon fasciatus* (pop. 1)	Common five-lined skink (Carolinian pop.)
Vascular plant	*Asplenium scolopendrium* var. *americanum*	American hart's-tongue fern
Vascular plant	*Carex alata*	Broad-winged sedge
Vascular plant	*Carex lupuliformis*	False hop sedge
Vascular plant	*Carex nigromarginata*	Black-edged sedge
Vascular plant	*Cirsium pitcheri*	Pitcher's thistle
Vascular plant	*Conioselinum chinense*	Chinese hemlock-parsley
Vascular plant	*Cypripedium candidum*	Small white lady's-slipper
Vascular plant	*Draba aurea*	Golden draba
Vascular plant	*Eleocharis equisetoides*	Horsetail spikerush
Vascular plant	*Erigeron hyssopifolius*	Daisy fleabane
Vascular plant	*Gratiola quartermaniae*	Limestone hedge-hyssop
Vascular plant	*Isotria medeoloides*	Small whorled pogonia
Vascular plant	*Malaxis paludosa*	Bog adder's-mouth
Vascular plant	*Platanthera leucophaea*	Eastern prairie fringed orchid
Vascular plant	*Rhododendron canadense*	Rhodora
Vascular plant	*Saxifraga paniculata*	Encrusted saxifrage
Vascular plant	*Solidago multiradiata*	Multi-rayed goldenrod
Vascular plant	*Tetraneuris herbacea*	Lakeside daisy
Vascular plant	*Triphora trianthophoros*	Nodding pogonia
Vascular plant	*Woodsia alpina*	Alpine woodsia

*For conservation ranks and basin presence, see Appendix B.

Figure 12. The boreal population of caribou (*Rangifer tarandus*) was the only mammal found to be highly vulnerable to climate change in an assessment of Ontario Great Lakes Basin species. Photo: Gerry Racey.

Factors most influencing vulnerability

Figure 13 shows the factors most consistently scored as having an increasing effect on climate change vulnerability of species in the Ontario Great Lakes Basin. They were related to species' sensitivity to temperature (historic and physiological thermal niche), distribution relative to barriers, and restriction to rare habitats and landforms (e.g., calcareous cliffs, alvars, and sand dunes). Each factor's effect varied with the species' distribution in the basin as it relates to direct exposures to past and projected local climate change. The representation of these factors may be biased depending on how much information was available about them. For example, factors related to a species' documented or modelled response to climate change requires published accounts in the peer-reviewed literature, but this information was not available for most species so could not often be assessed.

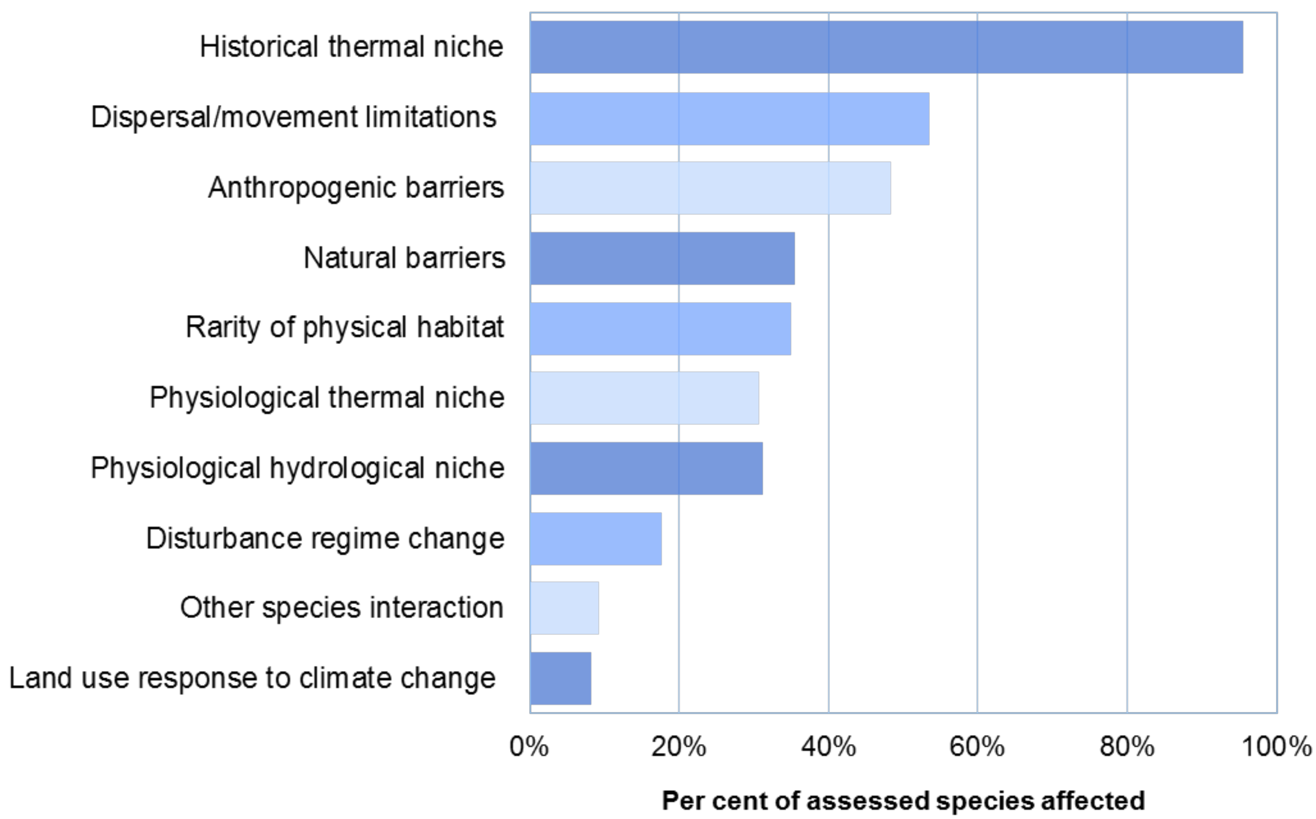

Figure 13. Factors that most influenced climate change vulnerability in an assessment of Ontario Great Lakes Basin species.

Thermal niche: Climate change models project large temperature changes in the Great Lakes Basin (McKenney et al. 2010). Species restricted to relatively cool aboveground or aquatic environments (Figure 14) are likely to be more vulnerable than those that prefer warmer environments. These cool environments include (but are not limited to) areas such as north-facing slopes, canyons and gorges, large peatlands and conifer swamps, coastal areas of Lake Superior, cold water streams, or the coldest water columns of large lakes. For example, rocky shoreline along Lake Superior provides cold-climate conditions for species with arctic-alpine affinities. Projected climate warming here in the winter months may lead to decreases in the duration and extent of lake ice cover and increases of surface water temperatures of 2.9 to 6 °C in the next century (Trumpickas et al. 2008, 2009). This may change species composition or encourage forest encroachment, resulting in a loss of habitat for disjunct arctic-alpine species. For this factor, species were evaluated against recent historical temperature changes (i.e., the past 50 years) and degree of specificity to cool environments.

Figure 14. Species associated with cool or cold conditions will likely have reduced habitat with rising temperatures. A) Geologic features such as the Aguasabon Gorge or B) extensive conifer swamps concentrate cool air pockets and limit sunlight providing habitat for species restricted to cold microclimates. Photos: Sam Brinker.

Dispersal/movement: Certain species will need to move in response to climate change. Those that can readily disperse over long distances or have flexible movement patterns are more likely to shift their distributions with changing climate envelopes than those with less ability to disperse. Species that rarely disperse outside of isolated patches, especially those with small ranges, will be more vulnerable. For example, vascular plants that have no obvious dispersal adaptations (other than rare chance events) will be more vulnerable than those that have evolved dispersal strategies such as fleshy fruits that are regularly dispersed by animals or winged seeds that are carried by wind (Figure 15).

Figure 15. Winged fruit like these 1-seeded samaras produced by American elm (*Ulmus americana*) are adapted for wind dispersal. The samaras of elms and other species such as ashes (*Fraxinus* spp.) and maples (*Acer* spp.) produce lift and drag to counter the forces of gravity as they drop, thereby reducing the rate of descent and increasing the distance they are transported by wind (Sharpe and Fields 1982). Photo: Sam Brinker.

Barriers: Species facing barriers to movement as climate envelopes shift are likely more vulnerable than those not affected by barriers. Here, barriers are considered those that act to limit or prevent movement or dispersal of a species. We determined barriers subjectively by considering species' movement ability and ecological tolerances:

- **Natural barriers:**
  - Absence of interconnecting aquatic features (rivers, lakes, streams, ponds, etc.) in upland habitat — aquatic species
  - Large areas of water (or in the case of islands, being encircled by water) — terrestrial species
  - Large areas of forest cover — species restricted to small open areas
- **Anthropogenic barriers**:
  - Major dams on large water bodies — aquatic species (Figure 16A)
  - Large areas of intensive urban and agricultural development (most common landform south of Highway 401 in southern Ontario) that limit dispersal of many terrestrial species of plants, reptiles and amphibians
  - Major travel corridors that divide previously continuous populations into smaller fragments, such as major highways for reptiles, mammals (Figure 16B)

Figure 16. A) Dams impede the upstream movement of aquatic species and were one of the barriers considered in an assessment of the climate change vulnerability of Ontario Great Lakes Basin species. Photo: Wasyl Bakowsky. B) Roads, railways, and other human-built structures can impede the movement of many reptiles and may result in death of individuals as well as restrict access to habitat components necessary for their survival. Photo: Sam Brinker.

Figure 17. Glacière talus is a rare vegetation community in the Ontario Great Lakes Basin that accumulates large amounts of snow and ice, forming as a result of frost and ice-wedging of bedrock. This habitat provides cold microclimates for disjunct arctic-alpine plants found nowhere else south of the Far North, such as at Cavern Lake Canyon near Thunder Bay pictured here. Photo: Sam Brinker.

Rarity of physical habitat: Species with less specific habitat needs are likely more resilient to climate change and better able to find suitable habitat as climate envelopes shift. Those with more specific needs for less common soil/substrate, geology, water chemistry, or features (e.g., caves, cliffs, alvars, active sand dunes, coastal marshes; Figure 17) will have less available habitat as climate envelopes shift so may be more vulnerable.

Hydrological niche: Climate change models project dramatic changes in precipitation in the Great Lakes Basin. Similar to thermal niche, species that have specific needs related to precipitation or wetland/aquatic habitat (e.g., springs, vernal pools, seepage slopes, fens; Figure 18) are likely more vulnerable to changes in seasonality of precipitation, altered flood dynamics, or net drying as climate change will likely result in reduced water budgets. Species that are less dependent on particular wetland habitat or hydrological regime are not likely to be significantly disrupted by changes in moisture conditions so are likely less vulnerable.

Figure 18. Shorter, warmer winters and longer summers will likely result in increased evapotranspiration and evaporation leading to decreased water levels in wetlands (Environment Canada 2013). For some wetlands, lower water levels can reduce species diversity and allow invasion by non-native species (Thomas et al. 2008) leaving some species more vulnerable. Photo: Sam Brinker.

Disturbance regime: Species requiring specific disturbance regimes (e.g., flooding frequency/intensity, ice scour) that are likely to be negatively affected by climate change or are susceptible to disturbances likely to increase in frequency (e.g., insect outbreaks, fires) are more vulnerable. For example, species that benefit from a lack of disturbance (e.g., those that are restricted to old growth forest) may be more vulnerable due to increased fire or drought as shorter fire cycles reduce forest stand age (Figure 19). In coastal areas, more intense storms and associated flash flooding may alter sensitive shoreline or benthic habitats.

Figure 19. Fire risk is projected to increase as climate changes (Le Goff et al 2009), particularly in the boreal forest region of the Ontario Great Lakes Basin making species confined to old growth forests potentially more vulnerable. Photo: Mitch Miller.

Other species interactions: Symbiotic relationships are essential for many organisms' survival. These interactions may be altered by climate change, leaving 1 or both species more vulnerable. For example, many orchids and mycorrhizal fungi have complex symbiotic associations where each of the orchid's life stages are dependent on both the presence of, and suitable abundance of, specific mycorrhizal fungi (e.g., Rock-Blake et al. 2017) for seeds to germinate and for the plants to absorb water/nutrients from the soil in exchange for carbohydrates. Because many orchids (Figure 20) cannot survive without these fungi, climate-related-changes to their mycorrhizal partners could make them more vulnerable.

Another potentially vulnerable group are lichens which consist of at least 2 unrelated organisms: a fungus that provides structure (and makes up most of the biomass) and a photosynthetic component, a green or blue-green algae (cyanobacteria) or sometimes both (Rikkinen 2015). For lichens to re-establish via spores (which only include the fungal portion of the lichen) they require the presence of appropriate algae for lichen-resynthesis. If climate change affects either the fungal or algal component, certain lichens may be particularly vulnerable.

Figure 20. Orchids such as the endangered small whorled pogonia (*Isotria medeoloides*) need specific fungal partners for successful seed germination and overall fitness, rendering them more vulnerable to climate change than species that do not have such needs. Photo: Sam Brinker.

Land use responses to climate change: Strategies to mitigate or adapt to climate change (reforestation, carbon storage, installation of windmills and solar farms, and hydropower development) could affect large areas of land and the species that depend on these areas in new ways (e.g., Johansson et al. 2018). Strategies designed for climate change mitigation may include reforestation projects, wind and solar projects (Figure 21), or construction of dams along major rivers to produce “greener” energy compared to coal or gas-fired plants. For example, concerns over fossil fuel use and influence on climate have resulted in development of more wind energy facilities, which have the capacity to affect certain species of bats and birds. This factor is difficult to address, as much uncertainty remains about the types of mitigation action that are likely to threaten habitats and species.

Figure 21. Changes in land use resulting from human responses to climate change have the potential to affect large areas of land and the species that depend on that area. The increase in renewable energy projects near coastal areas of the Ontario Great Lakes Basin may affect certain bird and bat species, but the net effect is not well understood. Photo: Bill Cole.

3.1 Patterns of vulnerability across taxonomic groups

Taxonomic groups have evolved different adaptations to their environment, so some are more vulnerable to climate change. Since the index factors are applied equally across taxonomic groups, we can make meaningful comparisons. We found that the most vulnerable groups in the Ontario Great Lakes Basin were molluscs, fishes, amphibians, and lichens; bryophytes and vascular plants were the next most vulnerable; the least vulnerable were birds, insects and spiders, and mammals (Figure 22). These results are consistent with similar climate change vulnerability assessments in other eastern North American jurisdictions. For example, Schlesinger et al. (2011) found all molluscs assessed in New York State to be vulnerable, just as all molluscs in the current study were vulnerable. In Michigan, Hoving et al. (2013) found that amphibians, molluscs, fishes, and insects were the most vulnerable groups, whereas mammals were among the least (though plants, lichens, and bryophytes were not assessed). In West Virginia, Byers and Norris (2011) found amphibians, followed by fishes and molluscs to be at most risk, versus birds and mammals. In Tennessee, fishes, molluscs, and plants were found to be the most vulnerable groups, while mammals, birds and reptiles were the least vulnerable (Glick et al. 2015). In Maine, Whitman et al. (2014) found fungi and lichens (an under-examined group in most assessments, limiting comparisons) and vascular plants among the most vulnerable species, citing many species reached their range limits in their assessment area contributing to higher rates of vulnerability in those groups. In the Ontario Great Lakes Basin, bryophytes and vascular plants were the next most vulnerable groups after molluscs, fishes, amphibians, and lichens. Interpreting results by taxonomic group should be done cautiously. Only a small proportion of species in the Ontario Great Lakes Basin was assessed, and expertise, distribution data, and scientific literature available to support assessment of each group varied. Following is an overview of the vulnerabilities of each assessed taxonomic group.

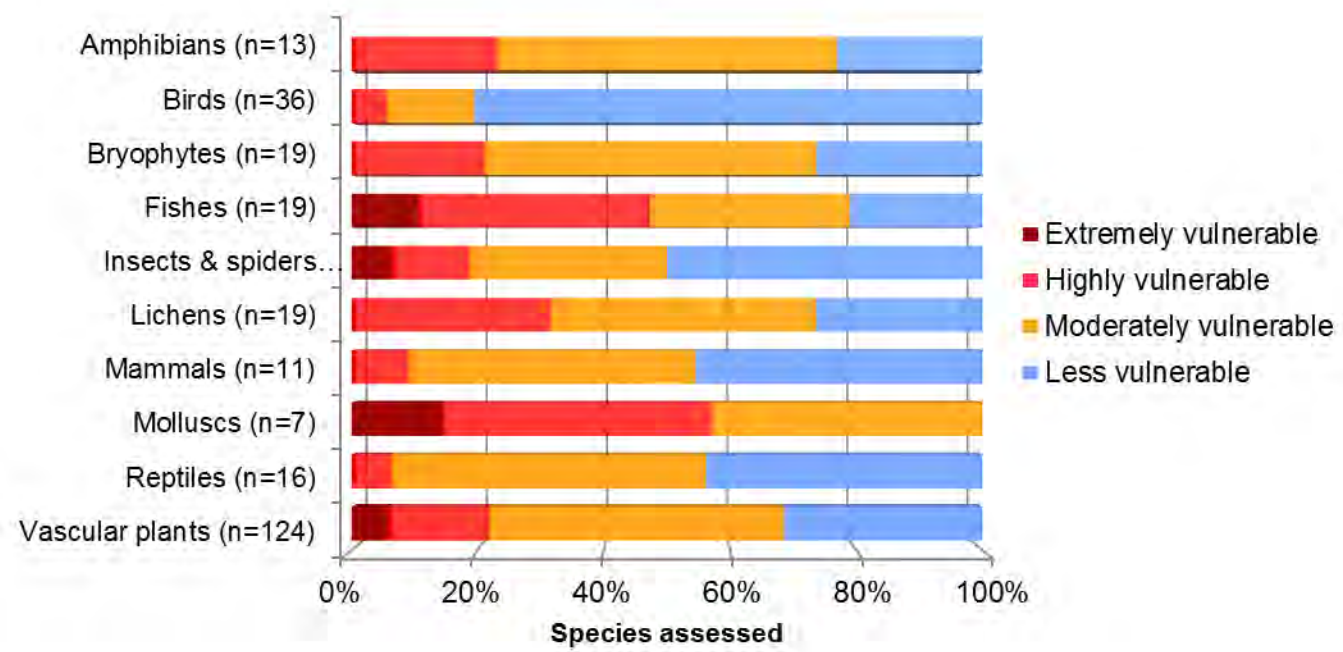

Figure 22. Climate change vulnerability by taxonomic group according to a study of Ontario Great Lakes Basin species.

Amphibians: Ten of the 13 amphibians were found to be vulnerable to climate change, with 3 being highly vulnerable and 6 moderately vulnerable. A significant vulnerability of many amphibians is their reliance on ephemeral pools to reproduce. Both the timing and duration of a wetland's hydroperiod (waterlogged phase) are highly correlated with amphibian breeding behaviour and success (Cary and Alexander 2003). If projected changes in precipitation and increased evaporation due to higher temperatures contribute to a decline in the quality and/or availability of these pools, some species' reproductive success may decline (Figure 23).

Figure 23. Northern dusky salamander (*Desmognathus fuscus*) is an example of an amphibian species found to be highly vulnerable to climate change as part of an assessment of the climate change vulnerability of Ontario Great Lakes Basin species — changes in precipitation could affect reproductive success of this and other amphibians. Photo: Rob Tervo.

Other important risk factors contributing to amphibian climate change vulnerability include anthropogenic barriers and limited dispersal ability. For example, Allegheny mountain dusky salamander (*Desmognathus ochrophaeus*) and northern dusky salamander (*Desmognathus fuscus*) are restricted to uncommon geological features (cool, moist talus slopes along the Niagara Escarpment), a rare habitat surrounded by intensive urban development.

Specialized thermal niche was also a risk factor, particularly for boreal chorus frog (*Pseudacris maculata*), which prefers cooler wetland types than most other amphibian species (McKenney et al. 1998) in the Ontario Great Lakes Basin. To a lesser extent, four-toed salamander (*Hemidactylium scutatum*) and pickerel frog (*Lithobates palustris*) are also more vulnerable because of their moderately specialized thermal niches.

Birds: Seven of the 36 birds assessed were found to be vulnerable to climate change, with 2 being highly vulnerable. As with other vulnerability assessments (e.g., Shank et al. 2014), ours concluded birds are generally less vulnerable to climate change than other taxonomic groups due to their excellent dispersal capabilities, which allow them to move long distances through unsuitable habitat and effectively colonize new habitat as it becomes available. Many also are opportunistic feeders having generalized diets that should allow them to switch among multiple food resources should one become less available with climate change. Species such as prairie warbler (*Setophaga discolor;* Figure 24) and Kirtland's warbler (*Setophaga kirtlandii*) may benefit from climate change because their habitat — treed rock barrens and regenerating jack pine (*Pinus banksiana*) stands — is disturbance maintained, relying on fire and drought which are projected to increase in frequency with climate change.

Another species that may benefit is barn owl (*Tyto alba*), whose Ontario breeding range is currently restricted to an area roughly 50 km inland of Lake Erie, likely due to the lake's climate-moderating effect (Ontario Barn Owl Recovery Team 2010). Warming temperatures may help it expand its range further inland in the Ontario Great Lakes Basin aided by its excellent dispersal ability (COSEWIC 2010).

Figure 24. Prairie warbler (*Setophaga discolor*) was found to be less vulnerable to climate change due in part to its preferred habitat, treed granitic rock barrens, which may benefit from climate change with increased incidence of fire and drought. Photo: Don Sutherland.

Vulnerability risk factors for some birds included specialized hydrological niche and restriction to uncommon geological features/habitat. For example, piping plover (*Charadrius melodus*) nests only on sand and pebble beaches on barrier islands, peninsulas, or shores of large lakes (Environment Canada 2013) and on freshwater dunes (COSEWIC 2013B), which are generally rare in the Ontario Great Lakes Basin. Aerial foragers were found to be particularly vulnerable because of their specialized diet. Species such as eastern whip-poor-will (*Antrostomus vociferus*), chimney swift (*Chaetura pelagica*), and barn swallow (*Hirundo rustica*) may be vulnerable if insect abundance is reduced or altered by a phenological response to climate change.

Bryophytes: Fourteen of the 19 bryophyte species assessed were found to be vulnerable to climate change. Like amphibians, bryophytes tend to be sensitive to changes in moisture, particularly the timing of appropriate wetness required for successful reproduction, an important factor in the establishment and maintenance of bryophyte populations (Vile et al. 2011). Studies have demonstrated an indirect negative effect of temperature increase on growth and productivity of peatland bryophytes due to increased evapotranspiration resulting in water budget deficits and thus negative water balance in mosses (e.g., Gunnarsson et al. 2004). This is of particular concern for some boreal peat mosses such as flat-leaved peat moss (*Sphagnum platyphyllum*) and feathery peat moss (*Sphagnum cuspidatum*), which are restricted to minerotrophic peatlands or edges of bog pools and kettle wetlands at their southern range limit in the basin.

Several assessed bryophytes are also particularly vulnerable because they rely on other species to generate habitat, making them more vulnerable than species that do not have such reliance. Brilliant red dung moss (*Splachnum rubrum*; Figure 25) and smooth-margin nitrogen moss *(Tetraplodon mnioides*) grow primarily on the dung of cervids (particularly moose and caribou) or canids (wolves, coyote) on small raised mounds in humid peatlands. They also rely on flies in the family Diptera that are attracted to mature spore-producing structures that exude foul-smelling compounds to disperse their spores (Christy 2006). Climate-induced changes to populations of cervids, canids, or dipterans such as range shifts, contractions, or declines could in turn affect the successful reproduction of these bryophytes.

Figure 25. Brilliant red dung moss (*Splachnum rubrum*) was found to be moderately vulnerable to climate change in an assessment of the Ontario Great Lakes Basin. Photo: Sam Brinker.

Fishes: Aquatic species appear more vulnerable than terrestrial species, and of the 19 fish species assessed, 15 were found to be vulnerable to climate change. Of these, 2 were extremely vulnerable and 7 highly vulnerable. Coldwater species were the most vulnerable because their habitats are predicted to decline as air temperatures warm and water temperatures rise. Redside dace (*Clinostomus elongatus*; Figure 26) and shortjaw cisco (*Coregonus zenithicus*) are both cool- to cold water species that are extremely vulnerable for this reason. Research suggests shallow lakes may lose refugia needed by other cold water species such as lake trout (*Salvelinus namaycush*) and brook trout (*Salvelinus fontinalis*) due to warmer summer temperatures caused by climate change, resulting in the loss of these species at their southern range edges (Jackson 2007, Shuter et al. 2012). Other risk factors include anthropogenic barriers restricting movement through habitat (e.g., dams, perched culverts), dependence on disturbance regimes (flood patterns) that climate change may disrupt, and habitat decline (water siltation, poorer water quality from polluted runoff).

Figure 26. Redside dace (*Clinostomus elongatus*) was found to be extremely vulnerable to climate change in assessment of Ontario Great Lakes Basin species. Photo: T. Roston.

Insects and spiders: Lack of information on the distribution and life history of many insects made it more difficult to assess this large and diverse group. Many species are small-bodied and hard to identify in the field. Thus, sufficient distributional data is often lacking to confidently map their range. For many we also do not have an adequate understanding of their diet, habitat requirements, or dispersal capabilities, with perhaps the exception of many Lepidoptera (butterflies and moths) and Odonata (dragonflies and damselflies), species that are better studied. Climate change has been linked to shifts in insect ranges to where they used to be absent, rare, or undetectable. For example, in recent years the range and number of observations of giant swallowtail (*Papilio cresphontes*) in the northeast was shown to have expanded/increased north in New York and Ontario in response to an absence of September frosts (Finkbeiner et al. 2011).

Eight of the 15 assessed insect/spider species were found to be vulnerable to climate change. The most vulnerable tend to have a narrow hydrological niche and depend on small headwater streams, minerotrophic fens, seepage slopes, or ephemeral ponds. Fens are vulnerable to changes in groundwater level, which plays a crucial role in the accumulation and decay of organic matter and governs plant community structure in these ecosystems (Seigel and Glaser 2006). If groundwater levels change as evapotranspiration increases with temperature, species restricted to these habitats may decline if the plant community changes.

Current climate change models project net drying of these specialized wetlands. Species such as eastern red damsel (*Amphiagrion saucium*) found in spring-fed calcareous wetlands, could be affected. Another risk factor is narrow thermal niche — species restricted to cool sites expected to warm with climate change could be affected. For example, sedge darner (*Aeshna juncea*) prefers northern peatlands or splash pools on the rocky shoreline of Lake Superior, both of which are cool environments that may become less suitable as temperatures change.

Other risk factors include major human-built and natural barriers for species with poor dispersal abilities, especially in mostly rural environments where small habitat patches are separated by large expanses of intensive agriculture. Garita skipperling (*Oarisma garita*) is mainly a prairie species with a disjunct population on Great La Cloche Island in the North Channel of Lake Huron. It is separated from other suitable habitat by large expanses of open water, acting as a natural barrier. The Lake Huron grasshopper (*Trimerotropis huroniana*; Figure 27), which is endemic to the Great Lakes Basin, is particularly vulnerable to climate change due partly to its restriction to open sand dunes, which have declined in quality and extent from human activity along Great Lakes shorelines.

Figure 27. Lake Huron grasshopper (*Trimerotropis huroniana*) was found to be highly vulnerable to climate change in the Ontario Great Lakes Basin. Photo: Colin Jones.

Species that are not dispersal limited, do not have specialized dietary needs, and are not restricted to rare habitat, such as the black purseweb spider (*Sphodros niger*; Figure 28), were most often found to be less vulnerable.

Figure 28. Black purseweb spider (*Sphodros niger*) was found to be less vulnerable to climate change in an assessment of species in the Ontario Great Lakes Basin. Photo: Colin Jones.

Lichens: Fourteen of the 19 lichen species assessed were found to be vulnerable to climate change. Key risk factors, particularly for species of conservation concern, include specialized thermal and hydrological niches. For example, alpine dot lichen (*Arthrorhaphis alpina*) is found only in sheltered canyons in the Ontario Great Lakes Basin, where it is disjunct from its main range to the north by over 1,500 km (Lewis and Brinker 2017), and is a relic of previous colder climates. Projected warming temperatures may favour shrub and tree encroachment into this species' open habitat, making it and other edge-of-range species in the basin, like crinkled snow lichen (*Flavocetraria nivalis*), particularly vulnerable.

Flooded jellyskin (*Leptogium rivulare*) is a semi-aquatic lichen that occupies certain deciduous swamps, floodplain forests and wooded vernal ponds (COSEWIC 2015A). It requires seasonal water fluctuations for growth and survival, and periodic disturbance (e.g. ice scour) brought upon by flooding for dispersal and habitat maintenance. Reduced spring runoff from lower snowpack along with more intense summer precipitation events may lead to changes in the timing and severity of hydrologic extremes affecting species with specialized niches such as flooded jellyskin. Others such as lungwort lichen (*Lobaria pulmonaria*), Pike's horsehair lichen (*Bryoria pikei*), Methuselah's beard lichen (*Usnea longissima*), yellow specklebelly lichen (*Pseudocyphellaria holarctica* Figure 29) and blistered jellyskin lichen (*Leptogium corticola*) are restricted to mature/old growth forests (Figure 30) or sheltered rocky coastal areas near Lake Superior that provide oceanic-like conditions including mild, wet winters, cool, moist summers, and high humidity/frequent fog. A warming climate with decreasing summer precipitation and less winter snow cover may make these species more prone to drying out thus increasing their vulnerability.

Figure 29. Yellow specklebelly lichen (*Pseudocyphellaria holarctica*) was found to be highly vulnerable to climate change in an assessment of the Ontario Great Lakes Basin. Photo: Sam Brinker.

Cyanolichens (those dependant on blue-green algal photobionts) such as yellow specklebelly lichen, fingered moon lichen (*Sticta beauvoisii*) and blistered jellyskin lichen require greater hydration than *chlorolichens* (those depending on only green algal photobionts) to be photosynthetically active to fix nitrogen (Lange et al. 1986), making them especially sensitive to moisture and temperature gradients (Ellis et al. 2009). Projected changes to mean annual temperature would lead to net warming and drying, likely reducing available moisture and humidity, affecting the photosynthetic activity of cyanolichens thereby increasing their vulnerability.

Figure 30. Old growth forests like this eastern white cedar (*Thuja occidentalis*) stand in the Ontario Great Lakes Basin provide unique microclimates and ecological continuity (long periods without major disturbances such as fire or logging) that are often lichen-rich and harbour species of conservation concern. Reduced snow cover and warmer and drier summers may reduce the habitat quality for certain lichens found in such habitat. Photo: Sam Brinker.

Several assessed lichens are also poor dispersers, a major limiting factor in their current distribution and a determinant of their future vulnerability, since they are less likely to occupy available habitat with shifting climate envelopes. For example, Methuselah's beard lichen is restricted to mature, humid conifer forests near large bodies of water in the Ontario Great Lakes Basin, and it only rarely produces the reproductive structures (apothecia) that allow it to disperse longer distances (Esseen et al. 1981). Rather it reproduces by thallus fragmentation, limiting its dispersal to very short distances in suitable habitat. If occupied habitat patches become unsuitable for this species, the local population is effectively lost.

Several lichens appear more able to cope with the effects of climate change: golden-eye lichen (*Teloschistes chrysophthalmus*), maritime sunburst lichen (*Xanthoria parietina*), and southern powdered Ruffle lichen (*Parmotrema hypotropum*) prefer well-lit, open habitat, often with a southern exposure, and have no major dispersal limitations so were found to be less vulnerable.

Mammals: Six of the 11 mammals assessed were found to be vulnerable to climate change, with the boreal population of caribou found to be highly vulnerable. In Ontario, caribou prefer colder minimum winter temperatures, deeper snow, and higher annual precipitation (Masood et al. 2017), all variables that climate change is likely to affect. For example, projected increases in minimum temperature by 2070 suggest that 95% of all caribou populations in Ontario may disappear (Masood et al. 2017). Reduced snow cover will reduce ice thickness on freshwater lakes and rivers (Brown and Duguay 2010), which may hinder caribou movement, especially for isolated populations on remote Lake Superior islands.

Other factors affecting caribou include the continuing expansion of white-tailed deer (*Odocoileus virginianus*) into its range, with resulting increases in competition and predation. And caribou prefer old growth boreal forest, which increased fire frequency could diminish (Sharma et al. 2013). However, some coastal Lake Superior caribou on isolated islands are found in habitat different from that typically found in contiguous boreal forest to the north, suggesting factors other than habitat type (e.g., predator avoidance) may be at play in determining habitat suitability.

Despite being comparatively unrestrictive to other taxonomic groups, anthropogenic barriers are a risk factor for some mammals, particularly American badger (*Taxidea taxus*). Extensive habitat loss and major highways are dispersal barriers limiting its successful dispersal due to road mortality (COSEWIC 2012).

Sensitivity to predators is a risk factor for snowshoe hare (*Lepis americanus*; Figure 31). Hares have a lower foot load than other species (Murray and Boutin, 1991), which provides them with an advantage over their predators in deep, soft snow. Changes in snow depth and snow conditions (e.g., snow hardness; Stenseth et al. 2004) resulting from climate change could influence hare survival by altering predator hunting success reducing the escape potential of hares. Snowshoe hares undergo seasonal moults to a white or brown coat colour to match the presence or absence of snow. Later onset of snow during fall and earlier spring melts would cause hares to be increasingly mismatched to their background, reducing their concealment from predators (Peers 2017). Climate change may also alter the relative importance of certain predators, especially in the southern part of the Ontario Great Lakes Basin, where species like coyote are benefiting from lower snowpack given their higher foot load disadvantage in deep snow (Murray and Boutin 1991).

Human response to climate change is a risk factor identified in the vulnerability index for some migratory bat species, including development of wind energy. However, *Myotis* bat species mortality at turbines has not been recorded often during migratory studies (e.g., 0–13%; Arnett et al. 2008) partly because they migrate shorter distances and in summer generally fly below turbine height (Reynolds 2006). As a group, bats in the Ontario Great Lakes Basin may be more vulnerable due to their specialized diet, being aerial insect foragers. Since precipitation is positively correlated with insect production, lower moisture availability may lead to lower insect abundance, which could reduce female bats' ability to recover from producing pups and store fat for hibernation (COSEWIC 2013A). And if winters are warmer and bats are roused more often during hibernation, their energy reserves and ability to survive the winter could be further reduced (Humphries et al. 2004).

Figure 31. Snowshoe hare was found to be moderately vulnerable to climate change in an assessment of species in the Ontario Great Lakes Basin. Photo: Far North Branch (MNRF).

Molluscs: Molluscs were the most vulnerable group assessed: 4 were extremely or highly vulnerable and 3 were moderately vulnerable. A common vulnerability was reliance on other species (fishes) to serve as glochidial (larval) hosts early in their life cycle. Adult molluscs are sedentary — they disperse via host fish transporting glochidia to new areas. If habitat becomes unsuitable during the adult phase, entire populations can be lost with no mechanism for dispersal. This is particularly concerning given that water quality declines associated with climate change are expected to further negatively affect this group. Under climate change, altered water depths and current velocities, as well as increases in turbidity and silt, may reduce availability of shallow, silt-free riffle habitat for some species. Anthropogenic barriers (dams) also restrict molluscs' ability to disperse across the basin further increasing their vulnerability. Invasive species are another risk factor threatening mussels. Zebra mussels (*Dreissena polymorpha*) have rendered much of the historical habitat for snuffbox (*Epioblasma triquetra*; Figure 32) unsuitable. An invasive fish species, the round goby (*Neogobius* *melanostomus*), may pose a new threat by competing with the mussel's 2 known larval host fishes and by eating juvenile mussels (COSEWIC 2011).

Figure 32. Snuffbox (*Epioblasma triquetra*) was found to be highly vulnerable to climate change in an assessment of species in the Ontario Great Lakes Basin. Photo: S. Staton.

Reptiles: Nine of 16 reptiles assessed were found to be vulnerable to climate change. Of these, only the Carolinian population of common five-lined skink (*Plestiodon fasciatus*) was found to be highly vulnerable, while the remaining 8 species were moderately vulnerable. As a group, reptiles were generally more resilient because they can tolerate warmer temperatures and have a more generalized diet. Both natural and anthropogenic barriers were primary risk factors for many however, especially for the Carolinian populations of five-lined skink and eastern foxsnake (*Pantherophis gloydi)*, both of which consist of a few small, localized populations in a heavily modified landscape where natural rescue or recolonization following local extinction would be unlikely (COSEWIC 2007A, 2008). Queensnake (*Regina septemvittata*) was the only species with a sufficiently specialized diet (based on the threshold of the CCVI), feeding almost exclusively on recently molted crayfish, making it moderately vulnerable (Gillingwater 2011). Specialized hydrological niches were important risk factors for both wood turtle (*Glyptemys insculpta*; Figure 33) and spotted turtle (*Clemmys guttata*).

Figure 33. Wood turtle was found to be moderately vulnerable to climate change in an assessment of the Ontario Great Lakes Basin. Photo: Sam Brinker.

Vascular plants: Eighty-five of the 124 assessed vascular plant species were found to be vulnerable to climate change. Risk factors varied widely, including natural and anthropogenic barriers, restriction to uncommon geological features (limestone pavement, diabase cliffs, talus slopes, marble barrens, etc.) and/or cold microclimates, dependence on particular natural disturbance regimes that climate change may alter, and preference for wetlands that may have net drying under climate change. Dispersal capability was a common risk factor for this group. Species with limited or no ability to disperse long distances were found to be particularly vulnerable. For example, goosefoot cornsalad (*Valerianella chenopodiifolia*) is found only in open rocky, deciduous woods on a remote island in Lake Ontario. With no specialized means of dispersal, its ability to colonize suitable habitat elsewhere is limited so one catastrophic event could eliminate the entire population.

Another risk factor for some plants was their strong dependence on specific wetland habitat (e.g., minerotrophic fens, vernal pools, seepage slopes) that is vulnerable if increasing temperatures alter local or regional water budgets. For example, branched bartonia (*Bartonia paniculata* ssp. *paniculata*; Figure 34) is restricted to poor fens that are maintained by specific water chemistry and hydroperiods. If climate change results in lowered water tables or altered nutrient cycling in these wetlands, shrubs and trees could take over reducing suitable habitat (Weltzin et al. 2003, Jassey et al. 2013).

Figure 34. A) Branched bartonia (*Bartonia paniculata* ssp. *paniculata*) was found to be moderately vulnerable to climate change in the Ontario Great Lakes Basin in part due to specialized hydrological niche. B) Typical fen habitat for branched bartonia is maintained by specific water chemistry and hydroperiods. Photos: Sam Brinker.

Some species may also be particularly sensitive to pathogens or pests that could increase or become more pathogenic due to climate change. Eastern hemlock (*Tsuga canadensis*) is sensitive to the decimating effects of a small aphid-like insect introduced from Asia, the hemlock woolly adelgid (*Adelges tsugae*), particularly where warm temperatures accelerate insect feeding and dispersal (Dukes et al. 2009). The incidence and spread of hemlock woolly adelgid is expected to increase with warming temperatures (Paradis et al. 2008), affecting more of eastern hemlock's range; it was found to be moderately vulnerable. Similarly, ash species (*Fraxinus* spp.) are highly susceptible to emerald ash borer (*Agrilus planipennis*), an invasive Asian wood boring beetle that is decimating ash populations as it spreads across the Ontario Great Lakes Basin. Both black ash (*Fraxinus nigra*) and pumpkin ash (*Fraxinus profunda*) were found to be moderately vulnerable partly due to this threat.

Thirty-nine plant species were found to be less vulnerable to the effects of climate change. The least vulnerable tended to be those that have few known risk factors or occupy less vulnerable habitats like warm, dry slopes or warm water bodies. Aquatic species of large rivers and lakes that produce propagules that easily disperse such as eastern mosquito fern (*Azolla cristata*) or

American lotus (*Nelumbo lutea*) were less vulnerable. Plants that produce bird or mammal-dispersed fruit such as eastern flowering dogwood (*Cornus florida*) or seeds that are wind dispersed were also found to be less vulnerable, since they can more easily track suitable climate envelopes and occupy new habitat. Other species could benefit from disturbances likely to increase with climate change, particularly those dependent on drought and fire. Pitch pine (*Pinus rigida*) was found to be less vulnerable because it's a fire-tolerant species with many adaptations such as bole and crown sprouting ability, thick bark, high resin content, and cones that open after fire (Hauser 2008). Other species such as oval-leaved bilberry (*Vaccinium ovalifolium)*, brittle prickly-pear (*Opuntia fragilis*) and bear oak can vigorously sprout following fire (Tirmentein 1990, Tayler 2005, Gucker 2006) and were also found to be less vulnerable.

3.2 Vulnerability of species by lake basin

The overall proportion of species vulnerable to climate change did not vary significantly by lake basin (Figure 35). On average, 56% of all species assessed in each basin were vulnerable to climate change (see Appendix B for which species occur in each basin). The Lake Superior Basin had the highest proportion of vulnerable species, with 64% found to be extremely, highly, or moderately vulnerable, followed by Lake Erie with 59%, Lake Huron with 57%, and Lake Ontario with 52%. The St. Lawrence River Basin had the lowest proportion of vulnerable species (48%). We used element occurrence data to do a preliminary assessment of concentration areas of the most vulnerable (extremely or highly) species by lake basin. Following is an overview of those results by lake.

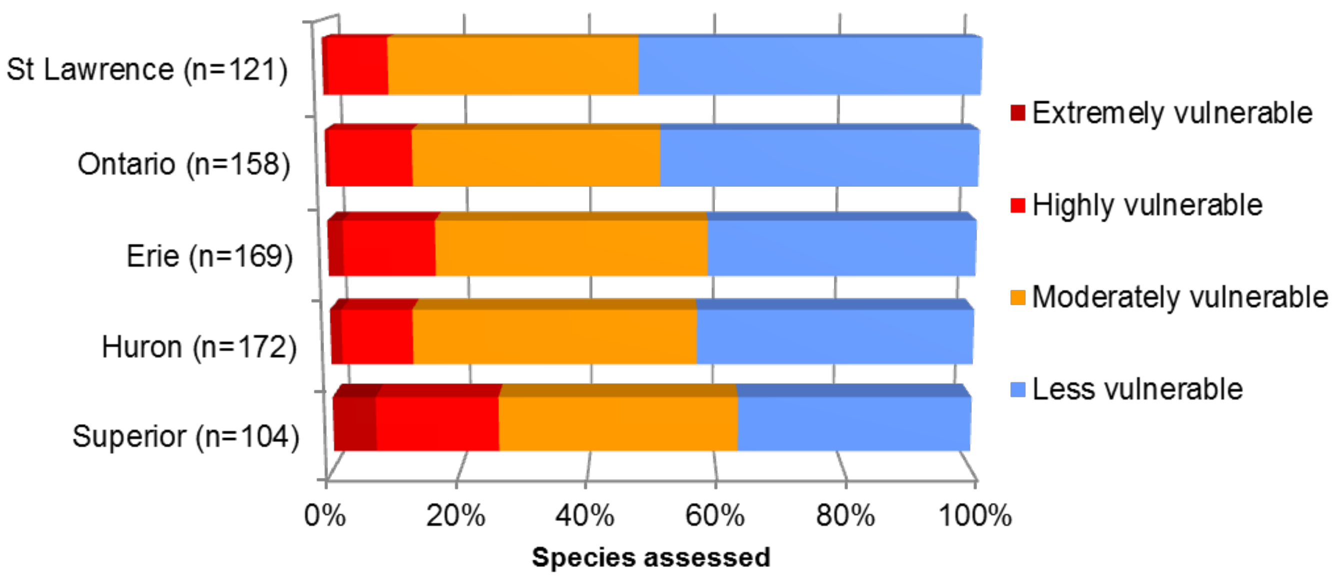

Figure 35. Percentage of species found to be vulnerable to climate change in an assessment of Ontario Great Lakes Basin species. Results are presented by lake basin.

Lake Superior Basin

The Lake Superior Basin is the northernmost, largest, and least environmentally affected Great Lakes sub-basin (Lake Superior Binational Program 2015). Sections of Minnesota, Wisconsin, Michigan, and Ontario are contained in the watershed. Compared to the other Great Lakes basins, it is sparsely populated and heavily forested with little agriculture due to a cool climate and poor, rocky soils. The botanical significance of the north shore of Lake Superior has long been known due to the many northern plants that occur here separated from their main areas of distribution in the Arctic (e.g., Agassiz 1850, Soper and Maycock 1963, Given and Soper 1981). The region also contains the several provincially rare vegetation types rarely found elsewhere in the watershed including Great Lakes Arctic-Alpine Basic Bedrock Shoreline, Basic Open Cliff, and Basic Open Talus, which typically occur on base-rich rock such as basalt and diabase (Bakowsky 1998, 2002).

The Lake Superior Basin had 67 species (64%) found to be vulnerable to climate change: 7 were extremely vulnerable (the most of any sub-basin), 20 were highly vulnerable, and 40 were moderately vulnerable. Table 4 provides a list of the most vulnerable species. Of all 5 basins, Lake Superior's had the highest percent of species found to be extremely or highly vulnerable, with 26% falling into 1 of these 2 categories. Taxa found to be extremely vulnerable: 1 fish and 5 vascular plants. Taxa found to be highly vulnerable: 3 fishes, 1 insect, 6 lichens, 1 mammal, 2 bryophytes, and 7 vascular plants.

Areas of greatest concern

Figure 36 shows the areas with the highest concentrations of extremely and highly vulnerable species observations. The Sibley Peninsula (including Sleeping Giant Provincial Park) east of Thunder Bay had the highest concentration of extremely and highly vulnerable species in the Lake Superior Basin, despite our assessing only a portion of the disjunct arctic-alpine species occurring there. Other important areas included parts of the Black Bay Peninsula, St. Ignace Island, the Slate Islands, Ouimet and Cavern Lake canyons, and coastal areas of Lake Superior from Rossport east to Marathon and the mouth of the Pic River. Coastal areas near Wawa (Figure 37) at Old Woman Bay and parts of Lake Nipigon such as at Orient Bay were also significant. These areas have important habitat for arctic-alpine flora where survival of these relictual species during both Quaternary cold and warm stages was likely supported by the cooling effect of Lake Superior (Given and Soper 1981). The harsh microclimate of exposed parts of Lake Superior and the effects of snow and ice, low summer temperatures, and fog continue to act as stressors and disturbance to maintain habitat for arctic-alpine species. This area also has habitat for boreal forest-dwelling caribou, a highly vulnerable species listed as threatened due to shrinking range and population (Thomas and Gray 2002).

Table 4. Lake Superior Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Taxonomic group	Scientific name	Common name	Score*
Bryophyte	*Aulacomnium acuminatum*	Acutetip groove moss	**HV**
Bryophyte	*Mielichhoferia mielichhoferiana*	Alpine copper moss	**HV**
Fish	*Acipenser fulvescens* pop. 1	Lake sturgeon (northwestern Ontario pop.)	**HV**
Fish	*Acipenser fulvescens* pop. 3	Lake sturgeon (Great Lakes-Upper St. Lawrence River pop.)	**HV**
Fish	*Coregonus zenithicus*	Shortjaw cisco	**EV**
Fish	*Ichthyomyzon fossor*	Northern brook lamprey	**HV**
Insect	*Trimerotropis huroniana*	Lake Huron grasshopper	**HV**
Lichen	*Arthrorhaphis alpina*	Alpine dot lichen	**HV**
Lichen	*Bryoria pikei*	Pike's horsehair lichen	**HV**
Lichen	*Flavocetraria nivalis*	Crinkled snow lichen	**HV**
Lichen	*Pseudocyphellaria holarctica*	Yellow specklebelly lichen	**HV**
Lichen	*Sticta beauvoisii*	Fingered moon lichen	**HV**
Lichen	*Usnea longissima*	Methuselah's beard lichen	**HV**
Mammal	*Rangifer tarandus*	Caribou (boreal population)	**HV**
Vascular plant	*Cirsium pitcheri*	Pitcher's thistle	**HV**
Vascular plant	*Draba aurea*	Golden draba	**HV**
Vascular plant	*Dryas drummondii*	Drummond's mountain avens	**EV**
Vascular plant	*Erigeron hyssopifolius*	Daisy fleabane	**HV**
Vascular plant	*Malaxis paludosa*	Bog adder's-mouth	**HV**
Vascular plant	*Oplopanax horridus*	Devil's club	**EV**
Vascular plant	*Pyrola grandiflora*	Arctic pyrola	**EV**
Vascular plant	*Saxifraga oppositifolia*	Purple mountain saxifrage	**EV**
Vascular plant	*Saxifraga paniculata*	White mountain saxifrage	**HV**
Vascular plant	*Silene acaulis*	Moss campion	**EV**
Vascular plant	*Solidago multiradiata*	Multi-rayed goldenrod	**HV**
Vascular plant	*Woodsia alpina*	Alpine woodsia	**HV**

*EV= extremely vulnerable; HV= highly vulnerable.

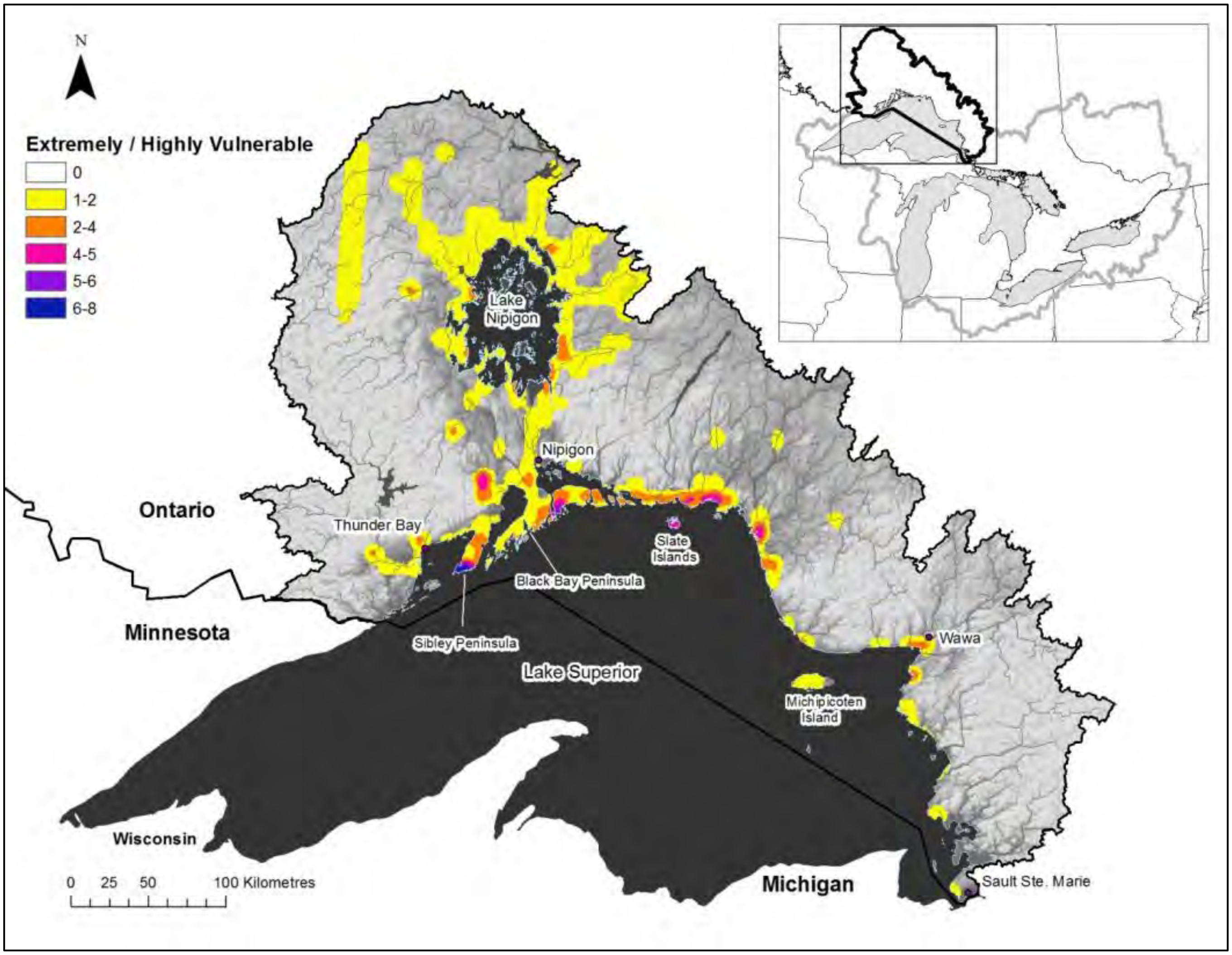

Figure 36. Density of Lake Superior Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Figure 37: Top: an aerial view of a rocky shoreline along Lake Superior in Pukaskwa National Park. Bottom left: these coastal areas are important refugia for arctic-alpine plants such as white mountain saxifrage (*Saxifraga paniculata*) found to be highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin. Bottom right: biologists document the location and abundance arctic-alpine plants in Pukaskwa National Park. Photos: Sam Brinker.

Lake Huron Basin

The Lake Huron Basin is the second largest Ontario Great Lakes sub-basin, comprising several distinct but interacting bodies of water — the North Channel, Georgian Bay, and Lake Huron proper. It drains the largest watershed in the basin and includes portions of Michigan and Ontario. Its southern part is intensively farmed, and is bisected by the Niagara Escarpment, which runs east from Michigan's Upper Peninsula, forming Drummond and Manitoulin Islands and the Bruce Peninsula which separates the main body of the lake from Georgian Bay. It has globally rare alvars, limestone cliffs and coastal sand dunes that support several species found nowhere else. The northern reaches of the basin are more heavily forested and dominated by Precambrian bedrock.

We found the Lake Huron Basin to have 97 species (57%) vulnerable to climate change: 3 were extremely vulnerable, 18 were highly vulnerable, and 76 were moderately vulnerable. Table 5 shows the 21 most vulnerable species. The Lake Huron Basin had the fourth highest proportion of vulnerable species found to be extremely or highly vulnerable with 13% falling into one of these 2 categories. Taxa found to be extremely vulnerable: 1 insect and 2 fishes. Taxa found to be highly vulnerable: 2 birds, 4 fishes, 2 molluscs, 1 insect, 1 bryophyte, 1 reptile and 7 vascular plants.

Areas of greatest concern

Figure 38 shows the areas with the highest concentrations of extremely and highly vulnerable species observations. Compared with the Superior and Erie basins, the Lake Huron basin had fewer concentration areas identified, and those identified were smaller in extent. Concentrations of extremely and highly vulnerable species were identified in the southern part of the watershed along Lake Huron in the Pinery Provincial Park to Port Franks area near Grand Bend and the lower reaches of the Ausable River. This river and its tributaries provide habitat for several globally rare fish and mollusc species, with vulnerabilities including barriers, specialized hydrological niches, and dependence on other species.

Other notable concentration areas occur along the southern shore of Manitoulin Island, which has globally rare alvars and Great Lakes coastal dunes. These ecosystems provide habitat for several endemic species found to be highly vulnerable including Lake Huron grasshopper, Pitcher's thistle (*Cirsium pitcheri*; Figure 39), and lakeside daisy, which will likely have less opportunity to migrate given their narrow habitat requirements.

Table 5. Lake Huron Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Taxonomic group	Scientific name	Common name	Score*
Bird	*Charadrius melodus*	Piping plover	**HV**
Bird	*Parkesia motacilla*	Louisiana waterthrush	**HV**
Bryophyte	*Bryoandersonia illecebra*	Spoon-leaved moss	**HV**
Fish	*Acipenser fulvescens* pop. 3	Lake sturgeon (Great Lakes-Upper St. Lawrence River pop.)	**HV**
Fish	*Ammocrypta pellucida*	Eastern sand darter	**HV**
Fish	*Clinostomus elongatus*	Redside dace	**EV**
Fish	*Coregonus zenithicus*	Shortjaw cisco	**EV**
Fish	*Ichthyomyzon fossor*	Northern brook lamprey	**HV**
Fish	*Moxostoma duquesnei*	Black redhorse	**HV**
Insect	*Atrytonopsis hianna*	Dusted skipper	**EV**
Insect	*Trimerotropis huroniana*	Lake Huron grasshopper	**HV**
Mollusc	*Epioblasma torulosa rangiana*	Northern riffleshell	**HV**
Mollusc	*Epioblasma triquetra*	Snuffbox	**HV**
Reptile	*Plestiodon fasciatus* pop. 1	Common five-lined skink (Carolinian population)	**HV**
Vascular plant	*Asplenium scolopendrium* var. *americanum*	American hart's-tongue fern	**HV**
Vascular plant	*Carex lupuliformis*	False hop sedge	**HV**
Vascular plant	*Cirsium pitcheri*	Pitcher's thistle	**HV**
Vascular plant	*Conioselinum chinense*	Chinese hemlock-parsley	**HV**
Vascular plant	*Erigeron hyssopifolius*	Daisy fleabane	**HV**
Vascular plant	*Platanthera leucophaea*	Eastern prairie fringed orchid	**HV**
Vascular plant	*Tetraneuris herbacea*	Lakeside daisy	**HV**

*EV= extremely vulnerable; HV= highly vulnerable.

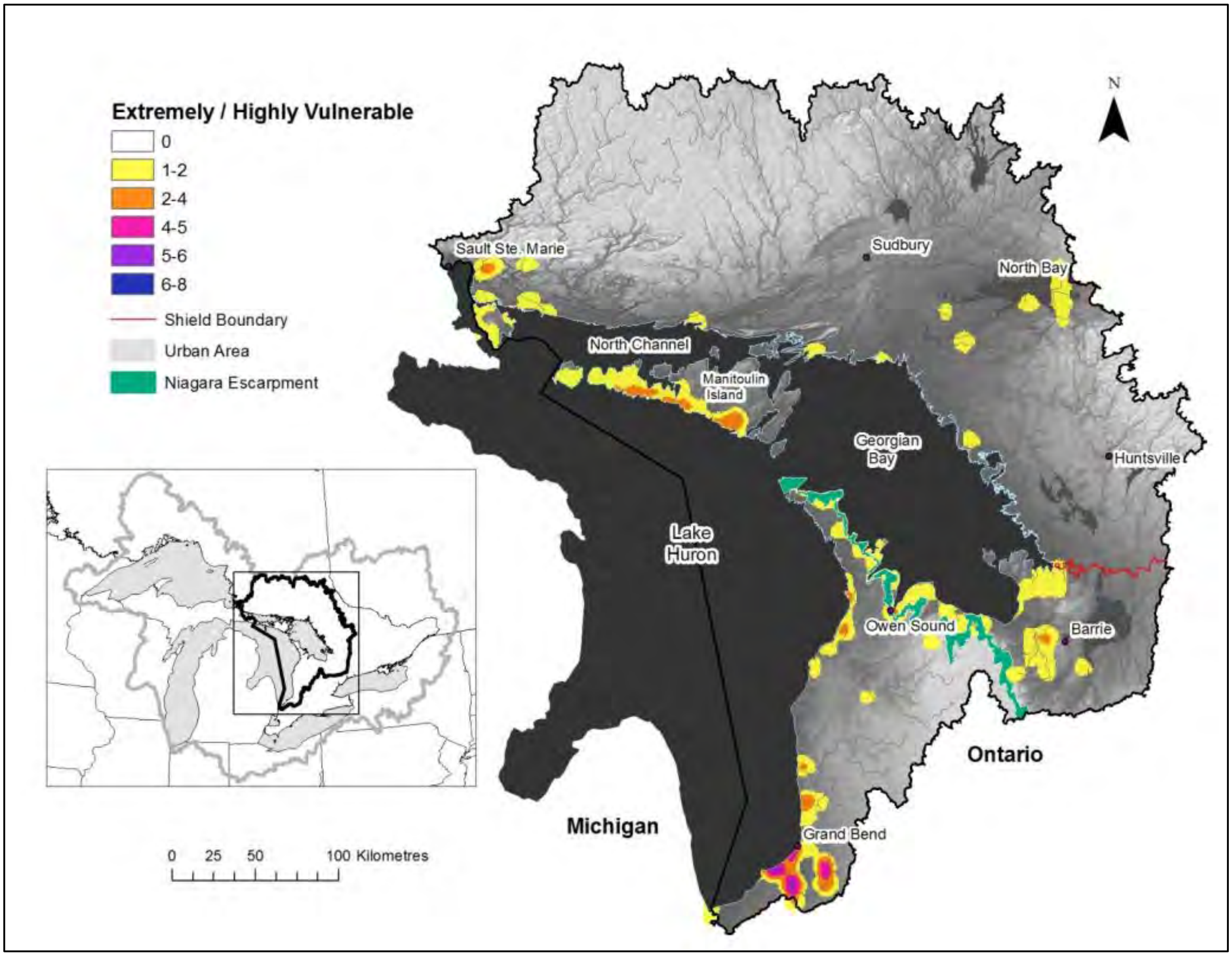

Figure 38. Density of Lake Huron Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Figure 39. Pitcher's thistle (*Cirsium pitcheri*) is a Lake Huron Basin species that was found to be highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin. It has very specific habitat requirements and is only found on Great Lakes dunes (primarily on Lake Huron). Photo: Sam Brinker.

Lake Erie Basin

The Lake Erie Basin is the most southern of the Ontario Great Lakes sub-basins. It is the shallowest and most productive, warming most rapidly in spring and freezing earliest in winter. It is also the most densely populated, with the most intensive farming and urbanization and the least remaining forest cover. The basin contains portions of Michigan, Indiana, New York, Ohio and Pennsylvania. Much of the basin is occupied by the Carolinian Zone (also known as the Eastern Deciduous Forest Region), and contains a diverse flora and fauna including many southern species at their northern range limits not found elsewhere in Ontario or Canada. The Carolinian Zone's northern boundary roughly coincides with a line from Toronto to Grand Bend, which dips south in the middle towards Lake Erie (Figure 40). All of the Carolinian Zone lies south of 44 degrees North Latitude.

We found 99 species (59%) in this basin to be vulnerable to climate change: 4 are extremely vulnerable, 24 are highly vulnerable, and 71 are moderately vulnerable. Table 6 lists the 28 most vulnerable species.

This basin had the second highest proportion (17%) of vulnerable species found to be extremely or highly vulnerable. Taxa found to be extremely vulnerable: 1 insect, 1 fish, 1 mollusc, and 1 vascular plant. Taxa found to be highly vulnerable: 1 amphibian, 2 birds, 6 fishes, 3 molluscs, 2 bryophytes, 1 reptile, and 9 vascular plants.

Table 6. Lake Erie Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Taxonomic group	Scientific name	Common name	Score*
Amphibian	*Anaxyrus fowleri*	Fowler's toad	**HV**
Bird	*Charadrius melodus*	Piping plover	**HV**
Bird	*Parkesia motacilla*	Louisiana waterthrush	**HV**
Bryophyte	*Bryoandersonia illecebra*	Spoon-leaved moss	**HV**
Bryophyte	*Tortula porteri*	Porter's Screw moss	**HV**
Fish	*Acipenser fulvescens* pop. 3	Lake sturgeon (Great Lakes-Upper St. Lawrence River pop.)	**HV**
Fish	*Ammocrypta pellucida*	Eastern sand darter	**HV**
Fish	*Clinostomus elongatus*	Redside dace	**EV**
Fish	*Ichthyomyzon fossor*	Northern brook lamprey	**HV**
Fish	*Lepisosteus oculatus*	Spotted gar	**HV**
Fish	*Moxostoma duquesnei*	Black redhorse	**HV**
Fish	*Percina copelandi*	Channel darter	**HV**
Insect	*Atrytonopsis hianna*	Dusted skipper	**EV**
Mollusc	*Epioblasma torulosa rangiana*	Northern riffleshell	**HV**
Mollusc	*Epioblasma triquetra*	Snuffbox	**HV**
Mollusc	*Simpsonaias ambigua*	Salamander mussel	**EV**
Mollusc	*Villosa fabalis*	Rayed bean	**HV**
Reptile	*Plestiodon fasciatus* pop. 1	Common five-lined skink (Carolinian pop.)	**HV**
Vascular plant	*Carex alata*	Broad-winged sedge	**HV**
Vascular plant	*Carex lupuliformis*	False hop sedge	**HV**
Vascular plant	*Carex nigromarginata*	Black-edged sedge	**HV**
Vascular plant	*Conioselinum chinense*	Chinese hemlock-parsley	**HV**
Vascular plant	*Cypripedium candidum*	Small white lady's-slipper	**HV**
Vascular plant	*Eleocharis equisetoides*	Horsetail spikerush	**HV**
Vascular plant	*Eleocharis geniculata*	Bent spikerush	**EV**
Vascular plant	*Isotria medeoloides*	Small whorled pogonia	**HV**
Vascular plant	*Platanthera leucophaea*	Eastern prairie fringed orchid	**HV**
Vascular plant	*Triphora trianthophoros*	Nodding pogonia	**HV**

*EV= extremely vulnerable; HV= highly vulnerable.

Areas of greatest concern

Figure 40 shows the areas with the highest concentrations of extremely and highly vulnerable species observations, all almost entirely restricted to the Carolinian Zone. Three of the concentration areas were on distinctive sandspits along the Lake Erie coast at Point Pelee, Rondeau, and Long Point (Figure 41), supporting a high proportion of species at risk, provincially rare species, and provincially and globally rare vegetation communities found nowhere else in the Ontario Great Lakes Basin (Dougan and Associates and McKay 2009).

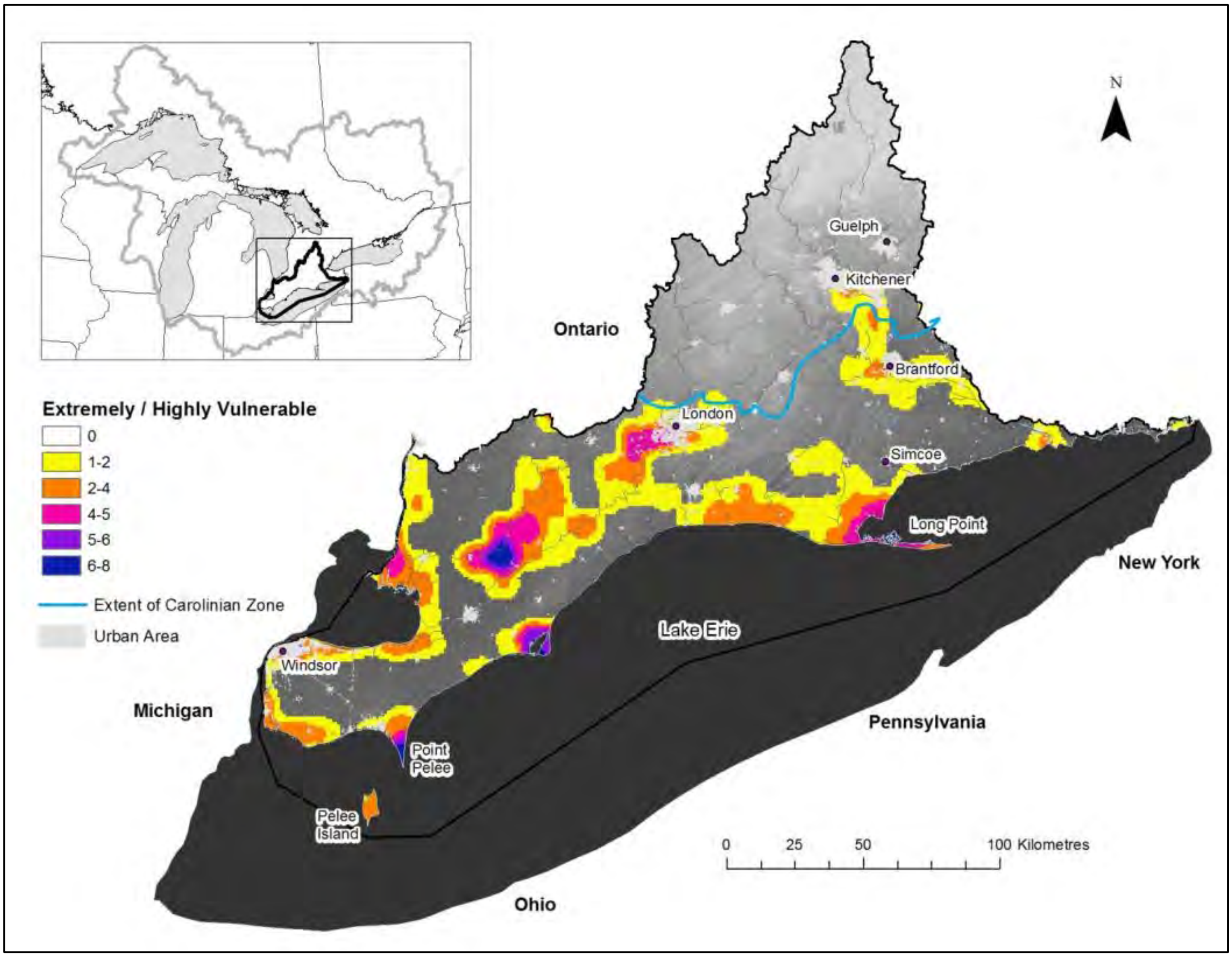

Figure 40. Density of Lake Erie Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Why are southern species associated with these ecosystems at their northern limit vulnerable given most climate models project warmer temperatures, which should favour southern species moving north? Human-built barriers are predicted to slow or stop species with poor dispersal abilities (Figure 42) from moving across a highly fragmented landscape. Rare vegetation communities associated with these ecosystems also tend to have a high proportion of species needing highly specialized habitat. With increasingly severe and more frequent storm events predicted, coastal ecosystems will be particularly vulnerable to erosion due to more intense waves and stronger currents. And if Great Lakes water levels drop, coastal wetlands will be disrupted or lost (e.g., Fracz and Chow-Fraser 2013), with less species diversity and increases in invasive species (Thomas et al. 2008).

Climate change is projected to greatly alter aquatic processes, dynamics, and biodiversity, affecting the distribution and abundance of many aquatic species. Several large Lake Erie Basin rivers (Sydenham, Thames, and to a lesser extent the Grand) harbour a disproportionately high number of vulnerable species, with the Sydenham having the highest concentration of extremely and highly vulnerable species, including the greatest diversity of freshwater mussels in Canada (Sydenham River Recovery Team 2002). Mussels are particularly vulnerable because they rely on other species (fishes) for dispersal so changes in host distribution or abundance will affect them. Vulnerable species associated with these rivers also depend greatly on flood patterns, pools, riffles, etc., that may be disrupted. Changes in seasonal precipitation and runoff patterns may alter the hydrological characteristics of aquatic habitats. Barriers such as dams also contribute to species vulnerability here.

Figure 41. Coastal sand dunes at Long Point National Wildlife Area on Lake Erie. These dunes support a high concentration of species found to be vulnerable to climate change in an assessment of the Ontario Great Lakes Basin. Photo: Sam Brinker.

Figure 42. Natural and anthropogenic barriers in the Lake Erie Basin were important factors in determining that the Carolinian population of common five-lined skink (*Plestiodon fasciatus*) was highly vulnerable to climate change as part of an assessment in the Ontario Great Lakes Basin. Photo: Colin Jones.

Lake Ontario Basin

The Lake Ontario Basin is the last in the chain of Great Lakes and receives the outflow from all of the other lakes and includes portions of Ontario and New York. It is the smallest of the Great Lakes sub-basins, its western part is the most heavily urbanized, and has the most rapidly expanding population in the Greater Toronto Area and surrounding Golden Horseshoe. Its central and eastern parts are dominated by farms and rural lands, and its northern parts are still largely forested. The Lake Ontario Basin includes the majority of the Oak Ridges Moraine, a 200 kilometre ridge of land that runs parallel to and about 60 kilometres north of Lake Ontario, and forms part of the watershed divide with Lake Huron. The moraine runs from the Niagara Escarpment in the west to the Trent River in the east. Its well-drained sandy soil provides habitat for prairie and savannah species with more western affinities. The southwestern part of the basin is bisected by the Niagara Escarpment running south from the

Lake Huron Basin through Niagara Falls and continuing into New York. The basin also contains notable concentrations of globally rare alvars found on the Nappanee Plain, a broad plateau of limestone between Belleville and Kingston. One of the greatest stresses on the lake is water levels being regulated through the St. Lawrence Seaway, which has altered the natural hydrologic cycle.

Our assessment showed 78 species (51%) to be vulnerable to climate change: 1 was extremely vulnerable, 18 were highly vulnerable, and 59 were moderately vulnerable. Table 7 shows the 19 most vulnerable species — this basin had the third highest proportion (13%) of vulnerable species found to be extremely or highly vulnerable. One fish was found to be extremely vulnerable. Taxa found to be highly vulnerable included 2 amphibians, 2 birds, 5 fishes, 2 bryophytes, 1 reptile, and 6 vascular plants.

Table 7. Lake Ontario Basin species found to be extremely or highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lakes Basin.

Taxonomic group	Scientific name	Common name	Score*
Amphibian	*Desmognathus fuscus*	Northern dusky salamander	**HV**
Amphibian	*Desmognathus ochrophaeus*	Allegheny mountain dusky salamander	**HV**
Bird	*Charadrius melodus*	Piping plover	**HV**
Bird	*Parkesia motacilla*	Louisiana waterthrush	**HV**
Bryophyte	*Bryoandersonia illecebra*	Spoon-leaved moss	**HV**
Bryophyte	*Tortula porteri*	Porter's screw moss	**HV**
Fish	*Acipenser fulvescens* pop. 3	Lake sturgeon (Great Lakes -Upper St. Lawrence River pop.)	**HV**
Fish	*Clinostomus elongatus*	Redside dace	**EV**
Fish	*Ichthyomyzon fossor*	Northern brook lamprey	**HV**
Fish	*Lepisosteus oculatus*	Spotted gar	**HV**
Fish	*Moxostoma duquesnei*	Black redhorse	**HV**
Fish	*Percina copelandi*	Channel darter	**HV**
Reptile	*Plestiodon fasciatus* pop. 1	Common five-lined skink (Carolinian pop.)	**HV**
Vascular plant	*Asplenium scolopendrium* var. *americanum*	American hart's-tongue fern	**HV**
Vascular plant	*Conioselinum chinense*	Chinese hemlock-parsley	**HV**
Vascular plant	*Cypripedium candidum*	Small white lady's-slipper	**HV**
Vascular plant	*Gratiola quartermaniae*	Limestone hedge-hyssop	**HV**
Vascular plant	*Platanthera leucophaea*	Eastern prairie fringed orchid	**HV**
Vascular plant	*Woodsia alpina*	Alpine woodsia	**HV**

*EV= extremely vulnerable; HV= highly vulnerable.

Areas of greatest concern

Figure 43 shows the areas with concentrations of the most vulnerable species observations. No areas were found to have concentrations of more than 4 extremely or highly vulnerable species.

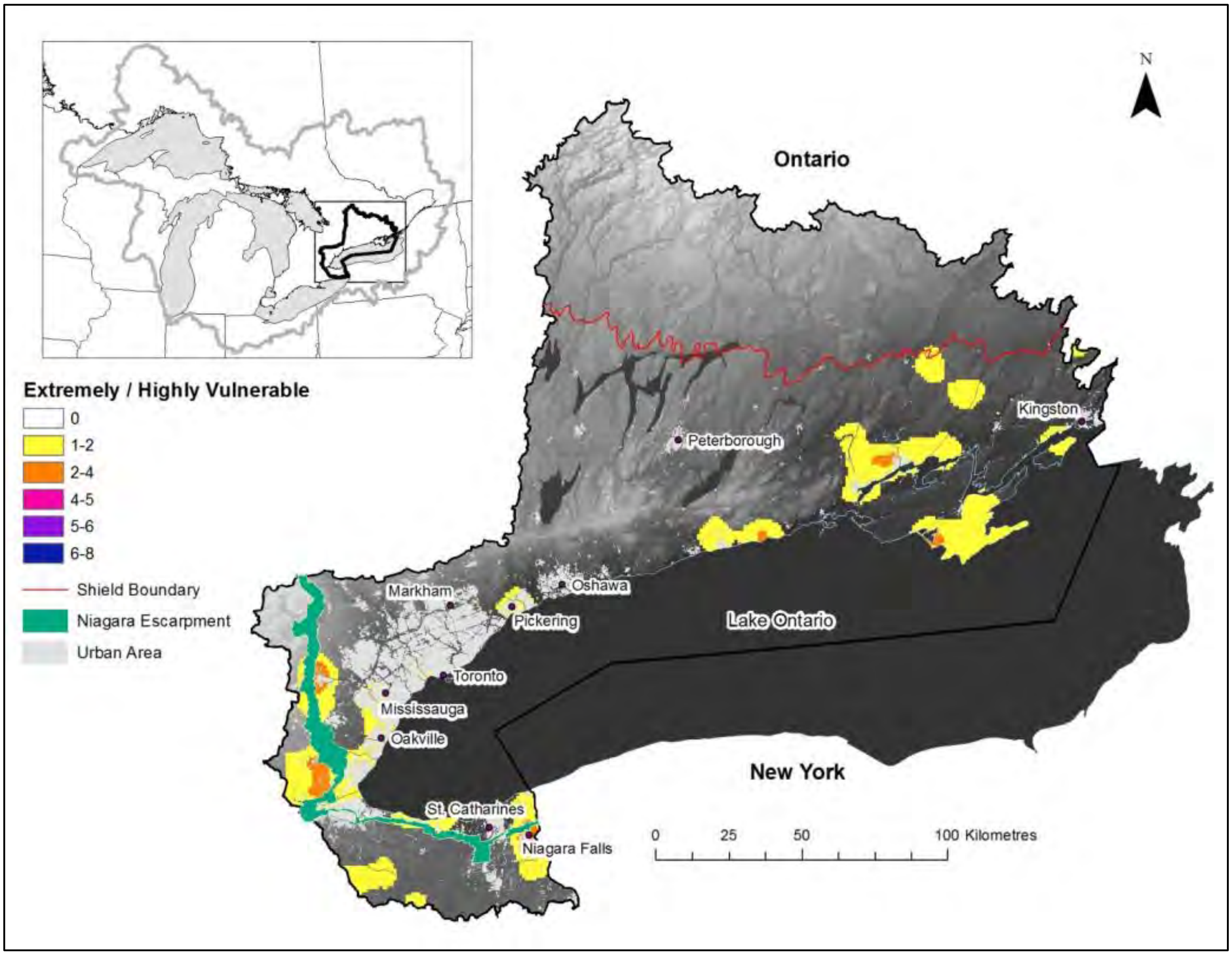

Figure 43. Density of Lake Ontario Basin species found to be extremely or highly vulnerable to climate change as part of an assessment of the Ontario Great Lakes Basin**.**

Several rivers and creeks in the Golden Horseshoe provide aquatic habitat for the most vulnerable species. For example, roughly 80% of the remaining Canadian population of redside dace (Figure 26), a globally rare fish, occurs here (COSEWIC 2007B), and is 1 of only 2 extremely vulnerable fish species we identified. The Niagara Gorge (Figure 44) provides habitat for the only populations of northern and Allegheny mountain dusky salamanders in the Ontario Great Lakes Basin. Both are vulnerable due to the extent of natural and anthropogenic barriers, their poor dispersal abilities, and their specialized hydrological niche. Porter's screw moss (*Tortula porteri*) is also found here and is restricted to solution cavities in moist dolomite boulders and north-facing walls of the gorge (Eckel 2004). Modelled climate projections suggest that suitable habitat for this species will contract if precipitation patterns are altered with projected climate change (R. Cameron, unpublished, cited in COSEWIC 2016). The Lake Ontario basin is the only part of the Ontario Great Lakes Basin where the highly vulnerable Limestone hedge-hyssop (*Gratiola quartermaniae*; Figure 45) has been found; this globally rare species is restricted to alvars mostly on the Napanee Limestone Plain (Estes and Small 2007). Its restriction to a rare geological feature, reliance on small ephemeral pools that form during spring rains, and its poor dispersal capabilities make it particularly vulnerable to climate change.

Figure 44. The Niagara Gorge along the Niagara River provides specialized habitat for both the northern dusky and Allegheny Mountain dusky salamanders (*Desmognathus fuscus*, *D. ochrophaeus*), both of which were found to be highly vulnerable to climate change in an assessment of the Ontario Great Lakes Basin. Photo: Sam Brinker.

Figure 45. Limestone hedge-hyssop (*Gratiola quartermaniae*) is a globally rare plant that has very specific habitat requirements, and has only been found in the Lake Ontario basin. It was found to be highly vulnerable to climate change in an assessment of Great Lakes Basin species. Photo: Sam Brinker.

St. Lawrence River Basin

The St. Lawrence River Basin is the primary drainage outflow of the Great Lakes Basin, connecting the Great Lakes to the Atlantic Ocean. It includes portions of Québec and New York. The Ontario portion runs from the eastern end of Lake Ontario to the Québec border. Water levels are regulated by several dams, including one in Ontario, the Moses-Saunders Dam at Cornwall. This basin's southern part is largely agricultural and rural, with several regional centres and the City of Ottawa. It includes the Thousand Island Archipelago, where a branch of the Canadian Shield known as the Frontenac Axis runs south across the river to join the Adirondacks in New York. North of Ottawa, the basin is mainly forested, paralleling the Ottawa River (including Lake Timiskaming) as far west as the watershed divide in the Algonquin highlands and north to the Kirkland Lake area.

In our assessment, the St. Lawrence River Basin was found to have 57 species predicted to be vulnerable to climate change: 1 was extremely vulnerable, 11 were highly vulnerable, and 45 were moderately vulnerable. Table 8 summarizes the 12 most vulnerable species. This basin had the lowest proportion of vulnerable species found to be extremely or highly vulnerable (10%). Only 1 taxa of fish was found to be extremely vulnerable. Taxa found to be highly vulnerable: 1 bird, 3 fishes, 1 insect, 1 lichen, and 5 vascular plants.

Table 8. St. Lawrence River Basin species found to be extremely or highly vulnerable to climate change in an assessment of the Ontario Great Lakes Basin.

Taxonomic group	Scientific name	Common name	Score*
Bird	*Parkesia motacilla*	Louisiana waterthrush	**HV**
Fish	*Acipenser fulvescens* pop. 3	Lake sturgeon (Great Lakes - Upper St. Lawrence River pop.)	**HV**
Fish	*Coregonus zenithicus*	Shortjaw cisco	**EV**
Fish	*Ichthyomyzon fossor*	Northern brook lamprey	**HV**
Fish	*Percina copelandi*	Channel darter	**HV**
Insect	*Callophrys lanoraieensis*	Bog elfin	**HV**
Lichen	*Sticta beauvoisii*	Fingered moon lichen	**HV**
Vascular plant	*Malaxis paludosa*	Bog adder's-mouth	**HV**
Vascular plant	*Platanthera leucophaea*	Eastern prairie fringed orchid	**HV**
Vascular plant	*Rhododendron canadense*	Rhodora	**HV**
Vascular plant	*Saxifraga paniculata*	White mountain saxifrage	**HV**
Vascular plant	*Woodsia alpina*	Alpine woodsia	**HV**

*EV= extremely vulnerable; HV= highly vulnerable.

Areas of greatest concern

No significant concentrations of extremely or highly vulnerable species were identified in the Ontario part of the St. Lawrence River Basin. Other notable areas included those associated with lake sturgeon (Figure 46) along the Ottawa River and its tributaries, from Lake Temiskaming (south of Kirkland Lake) and parts of the Ottawa River south towards its mouth at the St. Lawrence River (Figure 47). The Ottawa River has been highly fragmented by dams, and lake sturgeon have been observed only in un-dammed reaches (OMNR 2009). Another notable area was Alfred Bog where the largest population of Rhodora (Figure 48) in Ontario is found. The region also has the most southerly population of the alpine plant white mountain saxifrage (*Saxifraga paniculata*), which occurs on several cliffs such as Barron Canyon in Algonquin Provincial Park (Brayshaw 1964).

Figure 46. Lake sturgeon (*Acipenser fulvescens*) was found to be highly vulnerable to climate change in an assessment of Ontario Great Lakes Basin species. Human-built barriers (dams) restrict this species' access to spawning, nursery, and feeding habitat and limit its ability to migrate if current habitat becomes unsuitable with climate change. Photo: Tim Haxton.

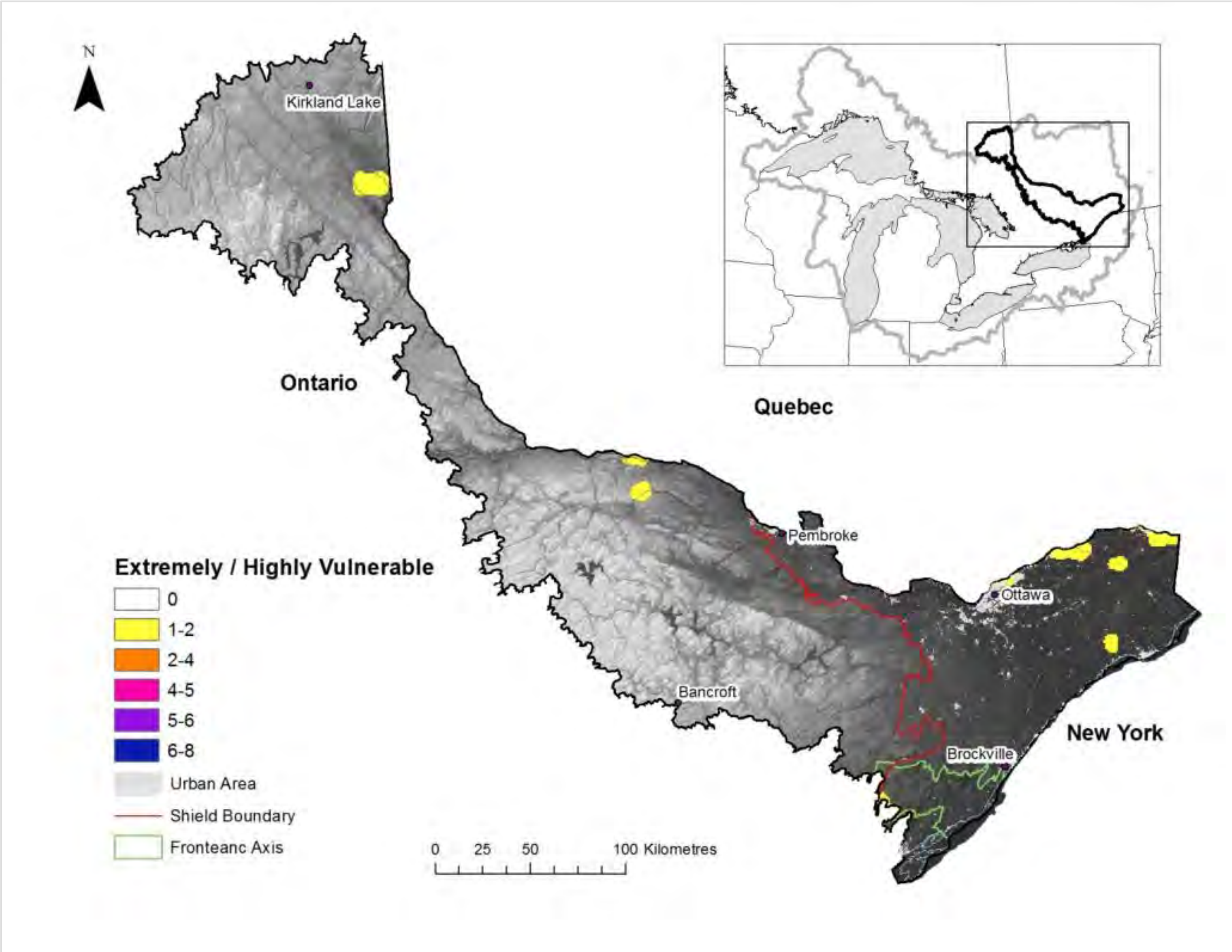

Figure 47. Density of St. Lawrence Basin species found to be extremely or highly vulnerable to climate change in an assessment of the Ontario Great Lakes Basin.

Figure 48. Rhodora (*Rhododendron canadense*) occurs only in the St. Lawrence River Basin and was found to be highly vulnerable to climate change in an assessment of the Ontario Great Lakes Basin. Photo: Sam Brinker.

3.3 Relationship between conservation status and vulnerability

Species of global or provincial conservation concern (critically imperilled, imperilled, vulnerable) or those at risk of extinction (endangered, threatened, of special concern) may be especially sensitive to climate change due to factors such as small population size or limited geographic range. Therefore, analyzing the link between vulnerability and conservation status may give a more complete picture of a species' conservation status under climate change.

We found that >80% of species with a high conservation status were vulnerable to climate change. However, species with high conservation status rank are not always found to be more vulnerable than secure ones. Schlesinger et al. (2011) found that in New York State, global conservation status rank of animals was unrelated to climate change vulnerability, except for the most globally imperilled species. However, a report on assessing the vulnerability of 73 plant species to climate change in Illinois found that globally rare plants were ranked vulnerable more often than common or invasive species (Baty et al. 2015). Similarly, Young et al. (2009) found that in Nevada, imperilled (statewide and globally) animals were predicted to be more vulnerable to climate change.

Species of global conservation concern

Figure 49 shows the per cent of species in each vulnerability category according to rounded global conservation status. Of all rankable species — excluding not rankable and unranked species — globally vulnerable species were the most vulnerable to climate change, followed by globally imperilled and then critically imperilled species. Globally secure species had the lowest proportion of vulnerable species followed by apparently secure species.

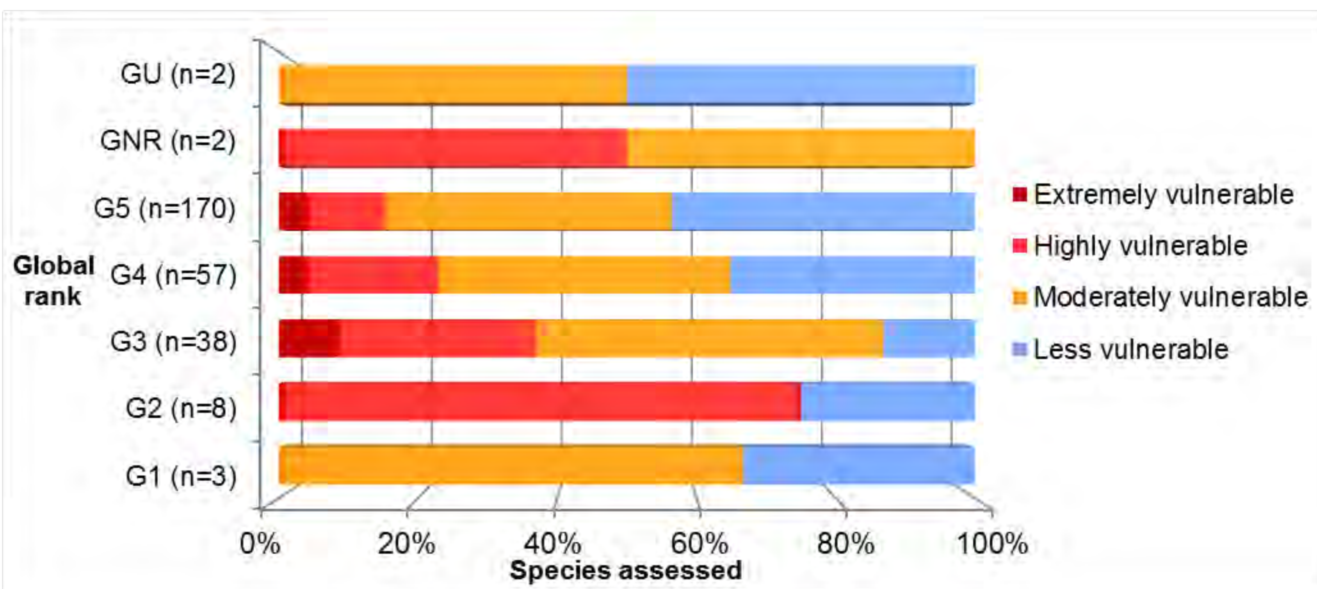

Figure 49. Relationship between global conservation status and climate change vulnerability of species assessed in the Ontario Great Lakes Basin. Global ranks: G1=critically imperilled, G2= imperilled, G3= vulnerable, G4=apparently secure, G5=secure, GNR=not ranked, GU=unrankable.

Eighty-four per cent (41 of 49) of vulnerable species were of conservation concern globally. However, global species of conservation concern were not proportionally more vulnerable than globally secure or apparently secure species. Only 24% of global conservation concern species were vulnerable to climate change, while 59% of globally secure and apparently secure species were vulnerable.

Some of the species of global conservation concern in the Ontario Great Lake Basin are endemic to the Great Lakes region and have risk factors making them particularly vulnerable to climate change (small, isolated ranges and specialized habitat needs). Notable concentrations of globally rare species in the Ontario Great Lakes Basin occur on the upper Bruce Peninsula and Manitoulin Island where some of the best remaining alvars occur (Figure 50). The rare, isolated and often specialized habitat associated with globally rare species in the basin reduces resilience to projected climatic change.

Figure 50. Globally rare alvars found on the Upper Bruce Peninsula and Manitoulin Island provide habitat for the Great Lakes endemic Lakeside daisy (*Tetraneuris herbacea*). Its poor dispersal abilities and confinement to a rare ecosystem resulted in it being found highly vulnerable in an assessment of climate change vulnerability in the Ontario Great Lake Basin. Photo: Sam Brinker.

Species of provincial conservation concern

Figure 51 presents the per cent of species in each vulnerability category according to rounded provincial status. Of all rankable species (excluding those ranked as status not applicable), historic and critically imperilled species were the most vulnerable to climate change, followed by provincially imperilled and vulnerable species. Apparently secure species had the lowest proportion of vulnerable species followed by secure species.

Much like global species of conservation concern, 86% of climate change vulnerable species were of conservation concern provincially. However, species of provincial conservation (e.g., Figure 52) concern were proportionally more vulnerable than provincially secure and apparently secure ones. Sixty-eight per cent species assessed that are of provincial conservation concern (rare throughout the province) were vulnerable to climate change, while 42% of provincially secure and apparently secure species were vulnerable.

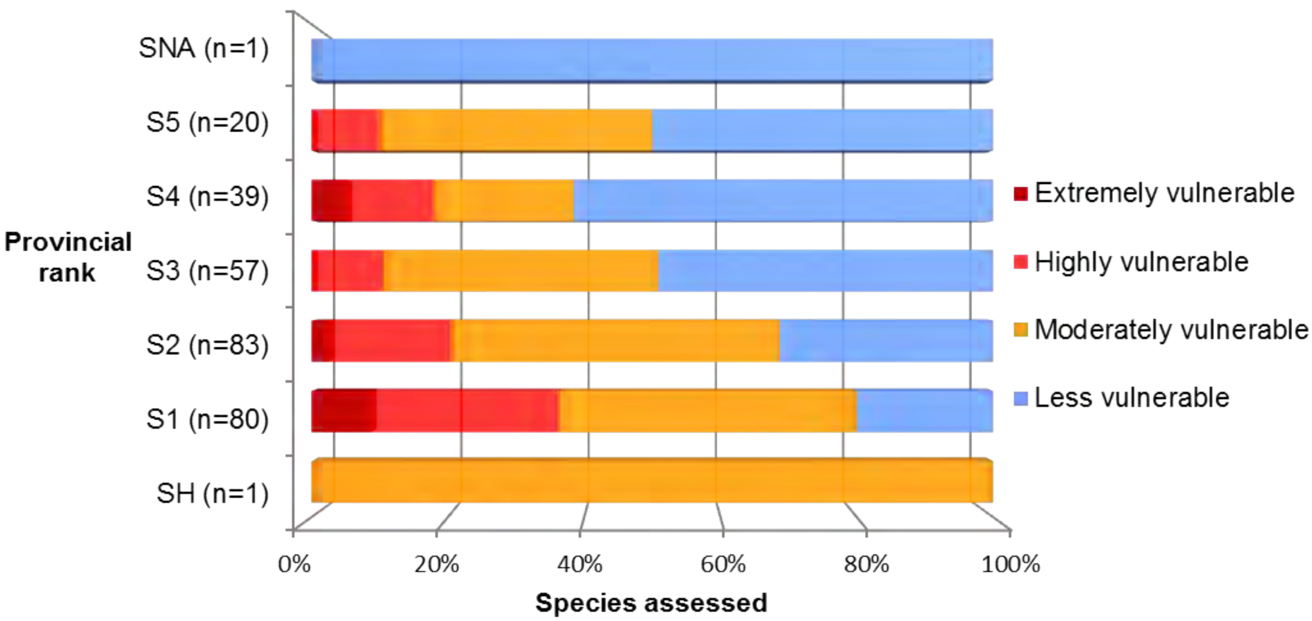

Figure 51. Relationship between provincial conservation status and climate change vulnerability for species assessed in the Ontario Great Lakes Basin. Provincial status ranks: SH= historic, S1=critically imperilled, S2= imperiled, S3=vulnerable, S4=apparently secure, S5=secure, SNA=not applicable (here, not native).

Figure 52. Species of provincial conservation concern such as West Virginia white (*Pieris virginiensis*) pictured here, were found to be proportionally more vulnerable to climate change than secure or apparently secure species in an assessment of climate change vulnerability in the Ontario Great Lakes Basin. Photo: Colin Jones.

Species at risk

Sixty-one per cent of the species we assessed are at risk of extinction, including those that the Committee on the Status of Species at Risk in Ontario (COSSARO) has assessed as endangered, threatened, or special concern. Figure 53 shows the relationship between assessed climate change vulnerability and COSSARO status.

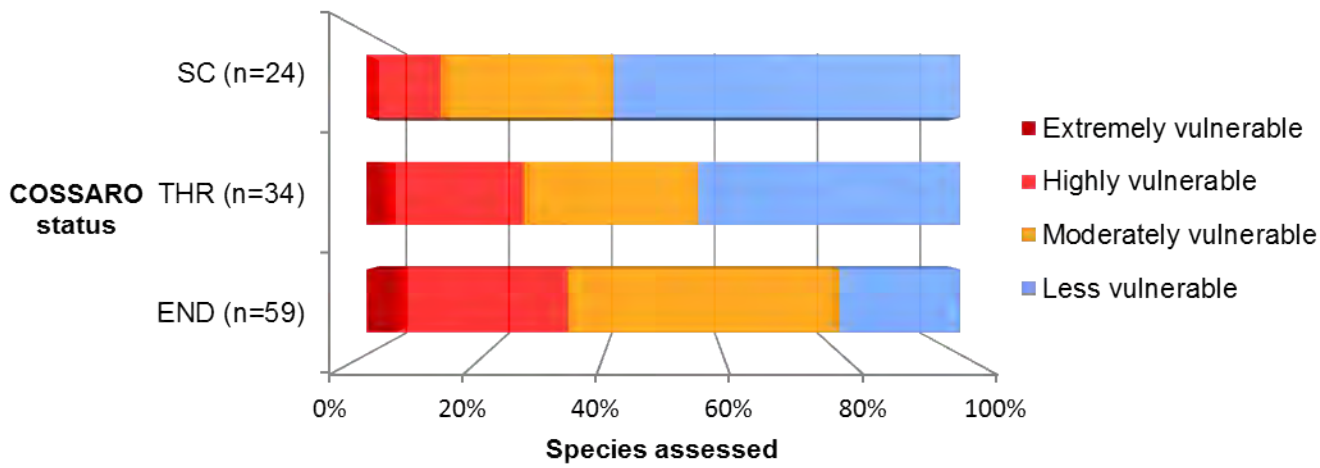

Figure 53. Relationship between climate change vulnerability and risk status (as per the Committee on the Status of Species at Risk in Ontario). SC=special concern, THR=threatened, END=endangered.

Endangered species (e.g., Figure 54) were assessed as the most vulnerable, with 80% being extremely, highly, or moderately vulnerable, while 56% of threatened species and 42% of special concern species were found vulnerable. Their small ranges and often specialized habitat requirements limit their adaptive capacity in the face of a changing climate to factors such as barriers to movement and availability of suitable habitat. Many species at risk are well studied, with more detailed information available for them, leading to more informed assessments.

Although a high proportion of at risk species were vulnerable to climate change, COSSARO-evaluated species at risk were not found to be more vulnerable to the effects of climate change than unlisted or species considered not at risk by COSSARO. Proportionally, unlisted and not at risk species were found to be only slightly more vulnerable to climate change than those at risk of extinction. Sixty-five per cent of species at risk were found to be vulnerable, while 62% of unlisted or not at risk species were vulnerable.

Figure 54. Of the endangered species included in this study, 80% were found to be vulnerable to climate change in the Ontario Great Lakes Basin. Pictured here is eastern prairie fringed orchid (*Platanthera leucophaea*), a species that is endangered in Ontario. Photo: Sam Brinker.

4 Conclusions

Climate change vulnerability assessments are a critical early step in adaptation planning and management. Our results can help resource managers define goals and identify and prioritize management plans to improve resiliency. They can also help in prioritizing which species' recovery and conservation plans should be revised to include information on potential climate effects. Identifying vulnerable species is essential, but it is also important to understand why particular species are vulnerable.

Our assessment of the Ontario Great Lakes Basin included 280 species in 10 taxonomic groups (amphibians, birds, bryophytes, fishes, insects and spiders, lichens, mammals, molluscs, reptiles, vascular plants). Of these, 175 (63%) were found to be vulnerable to climate change. Of those vulnerable species, 11 were extremely vulnerable, 49 were highly vulnerable, and 115 were moderately vulnerable.

While vulnerable species were found in all taxonomic groups, a disproportionate number are molluscs, fishes, amphibians, and lichens. The large numbers of birds (and to a lesser extent insects and spiders and reptiles) that were less vulnerable confirmed expectations and findings of other climate change species vulnerability assessments. The lower vulnerability of these taxa is in part due to their ability to disperse, more general habitat needs, or lack of strong dependence on particular hydrologic regimes or strong species interdependence (e.g., pollinator-plant relationships, plant-mycorrhizal fungi symbiosis).

In the Ontario Great Lakes Basin, the Lake Superior Basin had highest proportion of species (64%) vulnerable to climate change and the most species (26%) found to be extremely vulnerable of any sub-basin. The lakes Erie and Huron basins had the most vulnerable species, with 99 and 97 species respectively, followed by Lake Ontario (78), Lake Superior (67), and the St. Lawrence River (57).

A significant per cent (>80%) of species of global or provincial conservation concern or at risk of extinction according to COSSARO were found to be vulnerable to climate change. However, species with a high conservation status were not always more vulnerable than secure or apparently secure species.

A major uncertainty that the tool we used (Climate Change Vulnerability Index Release 3.0 — Canada; Young and Hammerson 2015) does not address is availability of suitable habitat in the future as species move and habitats change. And species in more fragmented habitats with poor dispersal capabilities will have less opportunity to move to new habitat in response to climate change. Future distributions will be determined not only by climate but also dispersal ability, biotic interactions (i.e., competition and predation), genetic adaptation, and abiotic factors (e.g., soil conditions).

Information from vulnerability assessments like ours can help inform policy and program development. For example, those working on species conservation initiatives can integrate this information into policy development and review for improved natural resource management outcomes. Our results also highlight the need for continued coordinated and centralized biodiversity and distribution data for all species of conservation concern, but particularly for groups such as invertebrates, lichens, and bryophytes, for which information is limited. Future adaptation strategies should include enhancing species-level monitoring to ensure the climate change effects are detected early and adaptation measures are effective. Future assessments should also include more common and widespread species.

5 Literature cited

Agassiz, L. 1850. Lake Superior: Its Physical Character, Vegetation, and Animals. Gould, Kendall and Lincoln, Boston, MA. 428 p.

Arnett, E.B., W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O'Connell, M.D. Piorkowski and R.D. Tankersley. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 71: 61–78.

Bakowsky, W.D. 1998. Rare communities of Ontario: Great Lakes arctic-alpine basic bedrock shoreline. Ontario Ministry of Natural Resources, Peterborough, ON. Natural Heritage Information Centre Newsletter 4(2): 10–11.

Bakowsky, W.D. 2002. Rare vegetation of Ontario: diabase cliffs of northwestern Ontario. Ontario Ministry of Natural Resources, Peterborough, ON. Natural Heritage Information Centre Newsletter 7(1): 12–15.

Baty, J., D.N. Zaya, G. Spyreas, B. Molano-Flores and T.J. Benson. 2015. Conservation of the Illinois flora: A climate change vulnerability assessment of 73 plant species. Illinois Natural History Survey, Champaign, IL.

Bowles, M.L. 1991. Eastern prairie fringed orchid *Platanthera leucophaea* (Nuttall) Lindley recovery plan. Prepared for Region 3 U.S. Fish and Wildlife Service, Fort Snelling, MN. 58 pp. <https://www.fws.gov/midwest/endangered/plants/pdf/epfoplan.pdf>. Accessed March 2018.

Brayshaw, T.C. 1964. Some interesting plant records from the Chalk River District. The Canadian Field-Naturalist 78: 150–154.

Brinker, S.R. 2017. Discovery of *Chamaenerion latifolium* (L.) Holub (Onagraceae) in the Great Lakes region. The Great Lakes Botanist 56: 3–9.

Brinker, S.R. and C.D. Jones. 2012. The vulnerability of provincially rare species (species-at-risk) to climate change in the Lake Simcoe watershed, Ontario, Canada. Ontario Ministry of Natural Resources, Peterborough, ON. Climate Change Research Report CCRR-31. 14 p.

Brooks, R.T. 2009. Potential impacts of global climate change on the hydrology and ecology of ephemeral freshwater systems of the forests of the northeastern United States. Climatic Change 95: 469–483.

Brown, L.C. and C.R. Duguay. 2010. The response and role of ice cover in lake-climate interactions. Progress in Physical Geography 34: 671–704.

Brownell, V.R. and J.L. Riley. 2000. The Alvars of Ontario: Significant natural areas in the Ontario Great Lakes region. Federation of Ontario Naturalists, Don Mills, ON. 269 p.

Byers, E. and S. Norris. 2011. Climate change vulnerability assessment of species of concern in West Virginia. West Virginia Division of Natural Resources, Elkins, WV. Project Report. 69 p. <https://wvdnr.gov/publications/PDFFiles/ClimateChangeVulnerability.pdf>. Accessed: March 2018.

Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage and A.R. Couturier (eds.). 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto, ON. 706 p. <http://www.birdsontario.org/atlas/index.jsp>. Accessed March 2018.

Cameron, R. No Date. Unpublished modelled climate projections for Porter's twisted [screw] moss (*Tortula porteri*). Cited in COSEWIC. 2016. COSEWIC assessment and status report on the Porter's twisted [screw] moss Tortula porteri in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 37 p.

Carey, C. and M.A. Alexander. 2003. Climate change and amphibian declines: Is there a link? Diversity and Distributions 9: 111–121.

Chen, I.C., J.K. Hill, R. Ohlemuller, D.B. Roy and C.D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. Science 333: 1024–1026.

Christy, J.A. 2006. *Tetraplodon mnioides* species fact sheet. U.S. Forest Service. Revised May 2007 by R. Huff, R. Holmes and D. Stone; revised August 2011 by Rob Huff. http://www.fs.fed.us/r6/sfpnw/issssp/documents/planning-docs/sfs-br-tetraplodon-mnioides-2011-08.doc. Accessed: March 2018.

[CNABH] Consortium of North American Bryophyte Herbaria. 2016. http://bryophyteportal.org/portal/index.php. Accessed: March 2018.

[CNALH] Consortium of North American Lichen Herbaria. 2016. http://lichenportal.org/portal/collections/harvestparams.php. Accessed: March 2018.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, VA. 83 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 98 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2007A. COSEWIC assessment and update status report on the five-lined skink *Eumeces fasciatus* (Carolinian population and Great Lakes/St. Lawrence population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 50 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2007B. COSEWIC assessment and update status report on the redside dace *Clinostomus elongatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 59 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2008. COSEWIC assessment and update status report on the eastern foxsnake *Elaphe gloydi*, Carolinian population and Great Lakes/St. Lawrence population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 45 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2010. COSEWIC assessment and status report on the barn owl *Tyto alba* (Eastern population and Western population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 34 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2011. COSEWIC assessment and status report on the snuffbox *Epioblasma triquetra* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 50 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2012. COSEWIC assessment and status report on the American badger *Taxidea taxus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 63 p. http://www.registrelepsararegistry.gc.ca/virtual_sara/files/cosewic/sr_blaireau_am_badger_1113_e.pdf Accessed: March 2016.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2013A. COSEWIC assessment and status report on the little brown myotis *Myotis lucifugus,* Northern Myotis *Myotis septentrionalis* and Tri-colored Bat *Perimyotis subflavus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 93 p.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2013B. COSEWIC assessment and status report on the piping plover *circumcinctus* subspecies (*Charadrius melodus circumcinctus*) and the *melodus* subspecies (*Charadrius melodus melodus)* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 39 p. http://www.registrelepsararegistry.gc.ca/virtual_sara/files/cosewic/sr_Piping%20Plover_2013_e.pdf Accessed: April 2016.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2015A. COSEWIC assessment and status report on the flooded jellyskin *Leptogium rivulare* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 48 p. http://www.registrelepsararegistry.gc.ca/virtual_sara/files/cosewic/sr_Flooded%20Jellyskin_2015_e.pdf Accessed: June 2017.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2015B. COSEWIC's Assessment Process and Criteria. Approved by COSEWIC in November 2015. http://www.cosewic.gc.ca/default.asp?lang=En&n=ED199D3B-1&printfullpage=true Accessed: January 2017.

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2016. COSEWIC assessment and status report on the Porter's twisted [screw] moss *Tortula porteri* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. 37 p.

Crins, W.J., P.A. Gray, P.W.C. Uhlig, and M.C. Wester. 2009. The Ecosystems of Ontario, Part 1: Ecozones and Ecoregions. Ministry of Natural Resources, Peterborough, Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR-01. 71 p.

Cross, M.S., E.S. Zavaleta, D. Bachelet, M.L. Brooks, C.A.F. Enquist, E. Fleishman, L.J. Graumlich, C.R. Groves, L. Hannah, L. Hansen, G. Hayward, M. Koopman, J.J. Lawler, J. Malcolm, J. Nordgren, B. Petersen, E.L. Rowland, D. Scott, S.L. Shafer, M.R. Shaw, and G.M. Tabor. 2012. The Adaptation for Conservation Targets (ACT) framework: A tool for incorporating climate change into natural resource management. Environmental Management 50: 341–351.

DeLeon, R.L., E.E. DeLeon, and G.R. Rising. 2011. Influence of climate change on avian migrants' first arrival dates. The Condor 113(4): 915–923.

Dobbyn, J.S. 1994. Atlas of the Mammals of Ontario. Federation of Ontario Naturalists, Don Mills, ON. 120 p.

Dougan & Associates, and V.L. McKay. 2009. An Ecosystem-based Recovery Strategy for the eastern prickly pear cactus (*Opuntia humifusa*) – Lake Erie Sand Spit Savannas in Canada (Draft).

Dubois, N., A. Caldas, J. Boshoven, and A. Delach. 2011. Integrating climate change vulnerability assessments into adaptation planning: A case study using the NatureServe Climate Change Vulnerability Index to inform conservation planning for species in Florida [Final Report]. Defenders of Wildlife, Washington, DC.

Dukes, J.S., J. Pontius, D. Orwig, J.R. Garnas, V.L. Rodgers, N. Brazee, B. Cooke, K.A. Theoharides, E.E. Stange, R. Harrington, J. Ehrenfeld, J. Gurevitch, M. Lerdau, K. Stinson, R. Wick, and M. Ayres. 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? Canadian Journal of Forestry Research 39: 231–248.

Eckel, P.M. 2004. Preliminary Cryptogamic (Moss, Lichen and Liverwort) Flora of the Canadian and American Gorge at Niagara Falls 1. Mosses. Res Botanica, a Missouri Botanical Garden Web site. http://www.mobot.org/plantscience/ResBot/index.htm Accessed: December 2016.

Ellis, C.J., R. Yahr, and B.J. Coppins. 2009. Local extent of old-growth woodland modifies epiphyte response to climate change. Journal of Biogeography 36: 302–313.

Ellwood, E.R., S.A. Temple, R.B. Primack, N.L. Bradley, and C.C. Davis. 2013. Record-breaking early flowering in the eastern United States. PLOS ONE 8(1): 1-9 e53788.

Environment Canada. 2013. Action Plan for the piping plover (*Charadrius melodus circumcinctus*) in Ontario. Species at Risk Act Action Plan Series. Environment Canada, Ottawa. 20 p.

Esseen, P.A., L. Ericson, H. Lindström, and O. Zackrisson. 1981. Occurrence and ecology of *Usnea longissima* in central Sweden. Lichenologist 13: 177–190.

Estes, D., and R.L. Small. 2007. Two new species of *Gratiola* (Plantaginaceae) from eastern North America and an updated circumscription for *Gratiola neglecta*. Journal of the Botanical Research Institute of Texas 1(1): 149–170.

Fay, M.F., M. Feustel, C. Newlands, and G. Gebauer. 2018. Inferring the mycorrhizal status of introduced plants of *Cypripedium calceolus* (Orchidaceae) in northern England using stable isotope analysis. Botanical Journal of the Linnean Society 186(4): 587–590.

Finkbeiner, S.D., R.D. Reed, R. Dirig, and J.E. Losey. 2011. The role of environmental factors in the northeastern range expansion of *Papilio cresphontes* Cramer (Papilionidae). Journal of the Lepidopterists' Society 65(2): 119–125.

Foden, W.B., S.H.M. Butchart, S.N. Stuart, J.C. Vie, H.R. Akcakaya, A. Angulo, L.M. DeVantier, A. Gutsche, E. Turak, L. Cao, S.D. Donner, V. Katariya, R. Bernard, R.A. Holland, A.F. Hughes, S.E. O'Hanlon, S.T. Garnett, C.H. Sekercioglu, and G.M. Mace.

2013. Identifying the world's most climate change vulnerable species: A systematic trait-based assessment of all birds, amphibians and corals. PLOS ONE 8(6): 1–13.

Fracz, A., and P. Chow-Fraser. 2013. Impacts of declining water levels on the quantity of fish habitat in coastal wetlands of eastern Georgian Bay, Lake Huron. Hydrobiologia 702: 151–169.

Furedi, M., B. Leppo, M. Kowalski, T. Davis, and B. Eichelberger. 2011. Identifying species in Pennsylvania potentially vulnerable to climate change. Pennsylvania Natural Heritage Program, Western Pennsylvania Conservancy, Pittsburgh, PA. 229 pp.

Garroway, C.J., J. Bowman, T.J. Cascaden, G.L. Holloway, C.G. Mahan, J.R. Malcolm, M.A. Steele, G. Turner, and P.J. Wilson. 2010. Climate change induced hybridization in flying squirrels. Global Change Biology 16: 113–121.

Gibson, S.Y., R.C. Van der Marel, and B.M. Starzomski. 2009. Climate change and conservation of leading-edge peripheral populations. Conservation Biology 23: 1369–1373.

Gillingwater, S.D. 2011. Recovery Strategy for the Queensnake (*Regina septemvittata*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, ON. 34 p.

Given, D.R., and J.H. Soper. 1981. The arctic-alpine element of the vascular flora of Lake Superior. National Museums of Canada Publications in Botany 10: 1-70.

Glick, P., S.R. Palmer, and J.P. Wisby. 2015. Climate Change Vulnerability Assessment for Tennessee Wildlife and Habitats. Report prepared by the National Wildlife Federation and The Nature Conservancy – Tennessee for the Tennessee Wildlife Resources Agency, Nashville, TN.

Government of Ontario. 2012. Ontario's Great Lakes Strategy. Unpublished Document. Toronto, ON. 71 p.

Graae, B.J., V. Vandvik, W.S. Armbruster, W.L. Eiserhardt, J.-C. Svenning, K. Hylander, J. Ehrlén, J. D.M. Speed, K. Klanderud, K.A. Bråthen, A. Milbau, O.H. Opedal, I.G. Alsos, R. Ejrnæs, H.H. Bruun, H.J.B. Birks, K.B. Westergarrd, H.H. Birks, and J. Lenoir. 2018. Stay or go – how topographic complexity influences alpine plant population and community responses to climate change. Perspective in Plant Ecology, Evolution and Systematics 30: 41–50.

Gucker, C.L. 2006. *Quercus ilicifolia*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/plants/shrub/queili/all.html Accessed: 20 December 2016.

Gunnarsson, U., G. Granberg, and M. Nilsson. 2004. Growth, production and interspecific competition in *Sphagnum*: Effects of temperature, nitrogen and sulphur treatments on a boreal mire. New Phytologist 163: 349–359.

Hamilton, J.A., and C.G. Eckert. 2007. Population genetic consequences of geographic disjunction: a prairie plant isolated on Great Lakes alvars. Molecular Ecology 16:1647–1660.

Hamon, W.R. 1961. Estimating potential evapotranspiration: Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers 87: 107–120.

Hampe, A., and R.J. Petit. 2005. Conserving biodiversity under climate change: The rear edge matters. Ecology Letters 8: 461–467.

Hauser, A.S. 2008. *Pinus rigida*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/plants/tree/pinres/all.html Accessed: 20 December 2016.

Hickling R., D.B. Roy, J.K. Hill, and C.D. Thomas. 2005. A northward shift of range margins in British Odonata. Global Change Biology 11: 502–506.

Hitch, A.T., and P.L. Leberg. 2007. Breeding distributions of North American bird species moving north as a result of climate change. Conservation Biology 21(2): 534–539.

Hoving, C.L., Y.M. Lee, P.J. Badra, and B.J. Klatt. 2013. Changing Climate, Changing Wildlife – A Vulnerability Assessment of 400 Species of Greatest Conservation Need and Game Species in Michigan. Michigan Department of Natural Resources, Wildlife Division Report No. 3564. 82 p.

Humphries, M.M., J. Umbanhowar, and K.S. McCann. 2004. Bioenergetic prediction of climate change impacts on northern mammals. Integrative and Comparitive Biology 44: 152–62.

[IPCC] Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. www.ipcc.ch/ipccreports/ar4-wg2.htm Accessed: January 2018.

[IPCC] Intergovernmental Panel on Climate Change. 2013. Summary for Policymakers. Pages 1–28 in T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley, editors. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York. 1535 p.

[IPCC] Intergovernmental Panel on Climate Change. 2014. Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: 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, p. 117–130.

[IJC] International Joint Commission. 2016. Protection of the waters of the Great Lakes. 2015 Review of the recommendations from the February 2000 report. 16 p. http://ijc.org/files/tinymce/uploaded/Publications/IJC_2015_Review_of_the_Recommendations_of_the_PWGL_January_2016.pdf Accessed: 5 January 2017.

Jackson, B. 2007. Potential effects of climate change on lake trout in Atikokan area. Climate Change Research Information Note Number 4, Ontario Ministry of Natural Resources, Sault Ste. Marie, ON.

Jassey, V.E., G. Chiapusio, P. Binet, A. Buttler , F. Laggoun-Défarge, F. Delarue, N. Bernard, E.A. Mitchell, M.-L. Toussaint, A.-J. Francez, and D. Gilbert. 2013. Above- and belowground linkages in *Sphagnum* peatland: climate warming affects plant-microbial interactions. Global Change Biology 19: 811–823.

Jensen, O.P., B.J. Benson, J.J. Magnuson, V.M. Card, M.N. Futter, P.A. Soranno, and K.M. Stewart. 2007. Spatial analysis of ice phenology trends across the Laurentian Great Lakes region during a recent warming period. Limnology and Oceanography 52(5): 2013–2026.

Johansson, M.U., C.A. Frisk, S. Nemomissa, and K. Hylander. 2018. Disturbance from traditional fire management in subalpine heathlands increases Afro-alpine plant resilience to climate change. Global Change Biology. https://doi.org/10.1111/gcb.14121 Accessed: 18 April 2018.

Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press, Cambridge, UK.

Keon, D.B., and P.S. Muir. 2002. Growth of *Usnea longissima* across a variety of habitats in the Oregon Coast Range. Bryologist 105(2): 233–242.

Klanderud, K. 2008. Species-specific responses of an alpine plant community under simulated environmental change. Journal of Vegetation Science 19: 363–372.

Klaus, S.P., and S.C. Lougheed. 2013. Changes in breeding phenology of eastern Ontario frogs over four decades. Ecology and Evolution 3(4): 835–845.

Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, D.R. Zak, R.L. Lindroth, S.C. Moser, and M.L. Wilson. 2003. Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C.

Lake Superior Binational Program. 2015. A Biodiversity Conservation Strategy for Lake Superior: A Guide to Conserving and Restoring the Health of the World's Largest Freshwater Lake. 20 p.

Lange, O.L., E. Kilian, and H. Ziegler. 1986. Water vapor uptake and photosynthesis of lichens: performance differences in species with green and blue-green algae as phycobionts. Oecologia 71: 104–110.

Lawler, J.J., T.H. Tear, C. Pyke, M.R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, L. Hannah, K. Klausmeyer, A. Aldous, C. Bienz, and S. Pearsall. 2010. Resource management in a changing and uncertain climate. Frontiers in Ecology and the Environment 8: 35–43.

Le Goff, H., M.D. Flannigan and Y. Bergeron. 2009. Potential changes in monthly fire risk in the eastern Canadian boreal forest under future climate change. Canadian Journal of Forestry Research 39: 2369–2380.

Lenoir, J., J.C. Gegout, P.A. Marquet, P. de Ruffray, and H. Brisse. 2008. A significant upward shift in plant species optimum elevation during the 20th Century. Science 320: 1768–1771.

Lesica, P., and B. McCune. 2004. Decline of arctic-alpine plants at the southern margin of their range following a decade of climatic warming. Journal of Vegetation Science 15: 679–690.

Lewis, C.J., and S.R. Brinker. 2017. Notes on new and interesting lichens from Ontario, Canada – III. Opuscula Philolichenum 16: 153–187. http://sweetgum.nybg.org/science/op/biblio_list.php?BucVolume_tab=16 Accessed December 2017.

Lofgren, B. M., F.H. Quinn, A.H. Clites, R.A. Assel, A.J. Eberhardt, and C.L. Luukkonen. 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs. Journal of Great Lakes Resources 28: 537–554.

Macnaughton, A., R. Layberry, C. Jones, and B. Edwards. 2016. Ontario Butterfly Atlas Online. Available: http://www.ontarioinsects.org/atlas_online.htm

Magnuson, J.J., K.E. Webster, R.A. Assel, C.J. Bowser, P.J. Dillon, J.G. Eaton, H.E. Evans, E.J. Fee, R.I. Hall, L.R. Mortsch, D.W. Schindler, and F.H. Quinn. 1997. Potential effects of climate changes on aquatic systems: Laurentian Great Lakes and Precambrian Shield region. Hydrological Processes 11: 825–871.

Masood, S., T.M. Van Zuiden, A.R. Rodgers, and S. Sharma. 2017. An uncertain future for woodland caribou (*Rangifer tarandus caribou*): the impact of climate change on winter distribution in Ontario. Rangifer 37(1): 11–30.

McDermid, J.L., S.K Dickin, C.L. Winsborough, H. Switzman, S. Barr, J.A. Gleeson, G. Krantzberg, and P.A. Gray. 2015. State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrological and Ecological Effects. Prepared jointly by the Ontario Climate Consortium and Ontario Ministry of Natural Resources and Forestry to advise Annex 9 - Climate Change Impacts under the Great Lakes Water Quality Agreement, October 2015.

McKenney, D.W, B.G. Mackey, J.P. Bogart, J.E. McKee, M.J. Oldham, and A. Chek. 1998. Bioclimatic and spatial analysis of Ontario reptiles and amphibians. Ecoscience 5(1): 18–30.

McKenney, D.W., J.H. Pedlar, K. Lawrence, P.A. Gray, S.J. Colombo, and W.J. Crins. 2010. Current and Projected Future Climatic Conditions for Ecoregions and Selected Natural Heritage Areas in Ontario. Climate Change Research Report CCRR-16, Applied Research and Development Branch, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, Canada. 42 p.

McCormick, M.K., D.L. Taylor, K. Juhaszova, R.K. Burnett, D.F. Whigham, and J.P. O'Neill. 2012. Limitations on orchid recruitment: not a simple picture. Molecular Ecology 21: 1511–1523.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao. 2007. Global climate projections. Pages 747–845 in: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY.

Mortsch, L., H. Hengeveld, M. Lister, B. Lofgren, F. Quinn, M. Silvitzky, and L. Wenger. 2000. Climate change impacts on the hydrology of the Great Lakes-St. Lawrence system. Canadian Water Resources Journal 25: 153–179.

Moss, R., M. Babiker, S. Brinkman, E. Calvo, T. Carter, J. Edmonds, I. Elgizouli, S. Emori, L. Erda, K. Hibbard, R. Jones, M. Kainuma, J. Kelleher, J.F. Lamarque, M. Manning, B. Matthews, J. Meehl, L. Meyer, J. Mitchell, N. Nakicenovic, B. O'Neill, R. Pichs, K. Riahi, S. Rose, P. Runci, R. Stouffer, D. van Vuuren, J. Weyant, T. Wilbanks, J.P. van Ypersele, and M. Zurek. 2008. Towards new scenarios for analysis of emissions, climate change, impacts and response strategies. IPCC Expert Meeting Report, 19-21 September, 2007, Noordwijkerhout, Netherlands, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland. 132 p.

Moss, R., J.A., Edmonds, K.A. Hibbard, M.R. Manning, S.K. Rose, D.P. van Vuuren, T.R. Carter, S. Emori, M. Kainuma, T. Kram, G. A. Meehl, J.F.B. Mitchell, N. Nakicenovic, K. Riahi, S.J. Smith, R.J. Stouffer, A.M. Thomson, J.P. Weyant and T.J. Wilbanks. 2010. The next generation of scenarios for climate change research and assessment. Nature 463: 747–756.

Murray, D., and S.A. Boutin. 1991. The influence of snow on lynx and coyote movements: does morphology affect behaviour? Oecologia 88(4): 463-469.

NatureServe 2002. Element Occurrence Data Standard. NatureServe, Arlington, VA. 201 p. http://downloads.natureserve.org/conservation_tools/element_occurence_data_standard.pdf. Accessed January 2017.

NatureServe. 2017. NatureServe Status and Ranking Definitions. http://explorer.natureserve.org/granks.htm. Accessed January 2017.

NatureServe. 2018. Conservation Status Assessment. http://www.natureserve.org/conservation-tools/conservation-status-assessment. Accessed January 2017.

[NHIC] Natural Heritage Information Centre. 2015. Element occurrence database. Ministry of Natural Resources and Forestry, NHIC, Peterborough, ON. Electronic database.

[NHIC] Natural Heritage Information Centre. 2016. Ontario Odonata Atlas Database. Maintained by the Ontario Ministry of Natural Resources and Forestry, Peterborough, ON.

Notaro, M., V. Bennington, and S. Vavrus. 2015. Dynamically downscaled projected of lake-effect snow in the Great Lakes basin. Journal of Climate (28): 1661–1684.

Ontario Barn Owl Recovery Team. 2010. Recovery strategy for the Barn Owl (*Tyto alba*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, ON. 31 p.

[OMNR] Ontario Ministry of Natural Resources. 2009. The lake sturgeon in Ontario. Fish and Wildlife Branch. Peterborough, Ontario. 48 p. + appends.

[OMNRF] Ontario Ministry of Natural Resources and Forestry. 2015. Five-Year Review of Progress Towards the Protection and Recovery of Species at Risk. Species Conservation Policy Branch, Peterborough, ON. 215 p.

Ontario Nature. 2016. Ontario Reptile and Amphibian Atlas Program. Available http://www.ontarionature.org/protect/species/herpetofaunal_atlas.php

Paradis, A., J. Elkinton, K. Hayhoe, and J. Buonaccorsi. 2008. Role of winter temperature and climate change on the survival and future range expansion of the hemlock woolly adelgid (*Adelges tsugae*) in eastern North America. Mitigation and Adaptation Strategies for Global Change 13(5): 541–554.

Peers, M.J.L. 2017. Predicting the fitness effects of climate change on snowshoe hares. InfoNorth 70(4): 430-434.

Reynolds, S. 2006. Monitoring the potential impact of a wind development site on bats in the northeast. Journal of Wildlife Management 70: 1219–1227.

Rikkinen, J. 2015. Cyanolichens. Biodiversity Conservation 24: 973–993.

Rock-Blake, R., M.K. McCormick, H.E.A. Brooks, C.S. Jones, and D.F. Whigham. 2017. Symbiont abundance can affect host plant population dynamics. American Journal of Botany 104: 72–82.

Root, T.L., J.T. Price, K.R. Hall, S.H. Scheider, C. Resenzweig, and J.A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421: 57–60.

Rowland, E.L., J.E. Davison, and L.J. Graumlich. 2011. Approaches to evaluating climate change impacts on species: A guide to initiating the adaptation planning process. Environmental Management 47: 322–337.

Schlesinger, M.D., J.D. Corser, K.A. Perkins, and E.L. White. 2011. Vulnerability of at-risk species to climate change in New York. New York Natural Heritage Program, Albany, NY. 61 p.

Schuter, B.J., A.G. Finstad, I.P. Helland, I. Zweimüller, and F. Hölker. 2012. The role of winter phenology in shaping the ecology of freshwater fish and their sensitivities to climate change. Aquatic Sciences 74: 637–657.

Shank, C.C., and A. Nixon. 2014. Climate change vulnerability of Alberta's biodiversity: A preliminary assessment. Biodiversity Management and Climate Change Adaptation project. Alberta Biodiversity Monitoring Institute, Edmonton, AB. 60 p.

Sharma, S., J.J. Magnuson, G. Mendoza, and S.R. Carpenter. 2013. Influences of local weather, large-scale climatic drivers, and the solar cycle on ice breakup dates; 1905-2004. Climatic Change 118: 857–870.

Sharpe, D.M., and D.E. Fields. 1982. Integrating the effects of climate and seed fall velocities on seed dispersal by wind: A model and application. Ecological Modelling 17: 297–310.

Siegel, D. and P. Glaser. 2006. Potential effects of climate change on spring fens and their endangered floral species. Geological Society of America Abstracts 38: 328.

Sneddon, L. A., and G. Hammerson. 2014. Climate change vulnerability assessments of selected species in the North Atlantic LCC Region. NatureServe, Arlington, VA.

Soper, J.H. and P.F. Maycock. 1963. A community of arctic-alpine plants on the east shore of Lake Superior. Canadian Journal of Botany 41: 183–198.

Stenseth, N.C., A. Shabbar, K.S. Chan, S. Boutin, E.K. Rueness, D. Ehrich, J.W. Hurrell, O.C. Lingjaerde and K.S. Jakobsen. 2004. Snow conditions may create an invisible barrier for lynx. Proceedings of the National Academy of Sciences of the United States of America 101(29): 10632–10634.

Still, S.M., A.L. Frances, A.C. Treher and L. Oliver. 2015. Using two climate change vulnerability assessment methods to prioritize and manage rare plants: A case study. Natural Areas Journal 35(1): 106–121.

Sydenham River Recovery Team. 2002. Recovery strategy for species at risk in the Sydenham River: An ecosystem approach. http://www.sydenhamriver.on.ca/Publications/RecoveryStrategyJuly2002.pdf Accessed: 25 January 2016.

Taylor, J.E. 2005. *Opuntia fragilis*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/plants/cactus/opufra/all.html Accessed: December 2016.

Thomas, D.C. and D.R. Gray. 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON.

Thomas, R., A. Kane, Environmental Law Institute, and B.G. Bierwagen. 2008. Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research. U.S. Environmental Protection Agency Papers. 51 p. http://digitalcommons.unl.edu/usepapapers/51 Accessed: January 2017.

Tirmentein, D. 1990. *Vaccinium ovalifolium*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/plants/shrub/vacovl/all.html Accessed: 20 December 2016.

[TNC] The Nature Conservancy. 2000. Toward a new conservation vision for the Great Lakes region: A second iteration. The Nature Conservancy, Great Lakes Program, Chicago, IL. 44 p.

Trumpickas, J., B.J. Shuter and C.K. Minns. 2008. Potential changes in future surface water temperatures in the Ontario Great Lakes as a result of climate change. Ontario Ministry of Natural Resource, Applied Research and Development Branch, Sault Ste. Marie, ON. Climate Change Research Information Note. CCRN-07. 10 p.

Trumpickas, J., B.J. Shuter and C.K. Minns. 2009. Forecasting impacts of climate change on Great Lakes surface water temperatures. Journal of Great Lakes Research 35: 454-463.

Tuberville, T.D., K.M. Andrews, J.H. Sperry and A.M. Grosse. 2015. Use of the NatureServe Climate Change Vulnerability Index as an assessment tool for reptiles and amphibians: Lessons learned. Environmental Management 56(4): 822–834.

[USGS] U.S. Geological Survey. 1999. Digital representation of Atlas of United States Trees (Volumes 1-3) by E.L. Little Jr. (1977). Digital Version 1.0. Available: https://www.sciencebase.gov/catalog/item/4fc518d1e4b00e9c12d8c362 van Herk, C.M., A. Aptroot and H.F. van Dobben. 2002. Long-term monitoring in the Netherlands suggests that lichens respond to global warming. Lichenologist 34(2): 141–154.

Vile, M.A., K.D. Scott, E. Brault, R. Kelman Wideer and D.H. Vitt. 2011. Living on the edge: The effects of drought on Canada's western boreal peatlands. Pp. 277–297 in Z. Tuba, N. G. Slack, and L. R. Stark (eds.). Bryophyte Ecology and Climate Change. Cambridge University Press, New York, NY. 506 p.

Weltzin, J.F., S.D. Bridgham, J. Pastor, J. Chen, and C. Harth. 2003. Potential effects of warming and drying on peatland plant community composition. Global Change Biology 9: 141–151.

Wetmore, C. 2002. Conservation assessment for *Pseudocyphellaria crocata* (L.) Vain. Prepared for USDA Forest Service, Eastern Region.

Whitman, A., A. Cutko, P. deMaynadier, S. Walker, B. Vickery, S. Stockwell and R. Houston. 2013. Climate Change and Biodiversity in Maine: Vulnerability of Habitats and Priority Species. Manomet Center for Conservation Sciences (in collaboration with Maine Beginning with Habitat Climate Change Working Group) Report SEI-2013-03. Brunswick, Maine. 96 p.

Williams, S.E., L.P. Shoo, J.L. Isaac, A.A. Hoffmann and G. Langham. 2008. Towards an integrated framework for assessing the vulnerability of species to climate change. PLoS Biology 6: 2621–2626.

Young, B. and G. Hammerson. 2015. Guidelines for using the NatureServe Climate Change Vulnerability Index, release 3.0 – Canada. NatureServe, Arlington, VA.

Young, B.E., E. Byers, K. Gravuer, K.R. Hall, G.A. Hammerson, A. Redder, K. Szabo and J. E. Newmark. 2009. Using the NatureServe Climate Change Vulnerability Index: A Nevada case study, NatureServe, Arlington, VA.

Young, B., K. Byers, K. Gravuer, K. Hall, G. Hammerson and A. Redder. 2010. Guidelines for using the NatureServe Climate Change Vulnerability Index. Release 2.01 – Canada. NatureServe, Arlington, VA.

Young, B.E., K.R. Hall, E. Byers, K. Gravuer, G. Hammerson, A. Redder, and K. Szabo. 2012. Rapid assessment of plant and animal vulnerability to climate change. Pp. 129–152 in J. F. Brodie, E. S. Post and D. F. Doak (eds). Wildlife Conservation in a Changing Climate. University of Chicago Press, Chicago, Illinois, USA.

Appendix A: Glossary

Vulnerability index scores (from Young and Hammerson 2015)

Extremely vulnerable (EV): Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.

Highly vulnerable (HV): Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.

Moderately vulnerable (MV): Abundance and/or range extent within geographical area assessed likely to decrease by 2050.

Less vulnerable (LV): Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will increase/decrease substantially by 2050. Actual range boundaries may change.

Individual risk factor scores

GI: Greatly increase vulnerability

Inc: Increase vulnerability

SI: Somewhat increase vulnerability

N: Neutral

U: Unknown

Global rank (Grank) (from NatureServe 2017, 2018)

Designation of rarity based on a species, subspecies, or variety's range-wide status; based on a consensus of experts with NatureServe's network of conservation data centres (NatureServe 2017).

G1 (critically imperilled): At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.

G2 (imperilled): At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

G3 (vulnerable): At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

G4 (apparently secure): Uncommon but not rare; some cause for long-term concern due to declines or other factors.

G5 (secure): Widespread and abundant.

GNR (not ranked): Not yet assessed.

GU (unrankable): Currently not assessable due to lack of information or greatly conflicting information about status or trends.

G#G# (range rank): A numeric range rank (e.g., G2G3, G1G3) used to indicate the range of uncertainty about the exact status of a taxon or ecosystem type.

G#T (infraspecific taxon): The status of infraspecific taxa (subspecies or varieties) indicated by a T-rank following the species' global rank. For example, the global rank of a critically imperilled subspecies of an otherwise widespread and common species would be G5T1.

SRANK (provincial rank)

Provincial (or subnational) ranks that the Ministry of Natural Resources' Natural Heritage Information Centre (NHIC) uses to set protection priorities for rare species and natural communities (not legal designations). Assigned similarly to global ranks but considering only those factors within the political boundaries of Ontario. Comparing global and provincial ranks allows the status, rarity, and urgency of conservation needs to be determined. NHIC continually evaluates provincial rankings and produces updated lists at least annually.

SH (possibly extirpated): Occurred historically in the province, could be rediscovered, but presence may not have been verified in the past 20 to 40 years; may be applied without the time delay if the only known occurrences were destroyed or if it had been extensively and unsuccessfully looked for. Reserved for species or communities for which some effort has been made to relocate occurrences, rather than simply using this status for all elements not known from verified extant occurrences.

S1 (critically imperilled): Extremely rare (often 5 or fewer occurrences) or especially vulnerable to extirpation from the province.

S2 (imperilled): Rare due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the province.

S3 (vulnerable): Vulnerable due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation from the province.

S4 (apparently secure): Uncommon but not rare in the province; some cause for long-term concern due to declines or other factors.

S5 (secure): Common, widespread, and abundant in the province.

SU (unrankable): Currently unrankable in the province due to lack of information or greatly conflicting information about status or trends.

SNA (not applicable): Not a suitable target for conservation activities in the province.

S#S# (range rank): Range of uncertainty about the status of a taxon or ecosystem type (e.g., S2S3, S1S3) in the province.

S#B (breeding): The species' breeding population in the province.

S#N (nonbreeding): The species' non-breeding population in the province.

S#? (inexact numeric rank): Indicates numeric rank is inexact.

General glossary

Adaptive capacity: The ability or potential of a species or system to respond to climate variability and change.

Bog: A peat-dominated wetland with a high water table and a surface carpet of mosses, chiefly sphagnum, characterized by the chemistry of the water, which is acidic.

Boreal: A Northern Hemisphere zone between 50 and 55° and 65 and 70° latitude characterized by cool northern temperatures and low annual rainfall.

Carolinian Life Zone: An area of southern Ontario (corresponding with Ecoregion 7E) with characteristic flora and fauna found farther south, namely the Carolina states.

Climate: Usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The typical period for averaging these variables is 30 years, defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind (IPCC 2014).

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer (IPCC 2013).

Confidence: A qualitative assessment of uncertainty as determined by evaluation of evidence and agreement.

Conservation status: NatureServe protocols for assessing extinction risk and assigning conservation status ranks; definitions of global, national, and subnational status ranks (NatureServe 2017).

Conservation status rank: Global, national, and subnational ranks (or G-ranks, N-ranks and S-ranks) widely used throughout the conservation community to measure extinction or extirpation risk of a taxon or ecosystem type (Nature Serve 2018). Based on a 1 to 5 scale, ranging from critically imperiled (1) to demonstrably secure (5). Status is assessed and documented at 3 distinct geographic scales - global (G), national (N), and state/province (S).

COSEWIC (Committee on the Status of Endangered Wildlife in Canada): An independent advisory panel to the Minister of Environment and Climate Change Canada that meets twice a year to assess the status of wildlife species at risk of extinction. Members are wildlife biology experts from academia, government, non-governmental organizations, and the private sector responsible for designating wildlife species in danger of disappearing.

COSSARO (Committee on the Status of Species at Risk in Ontario): An independent committee of experts that considers which plants and animals should be listed as at risk in Ontario. It consists of up to 12 members with expertise in scientific disciplines or Indigenous traditional knowledge.

Downscaling: a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution general circulation models (GCMs); involves examining the statistical relationship between past climate data and field measurements.

Ecoregion: A region characterized by a repetitive pattern of ecosystems that have similar climate and landform.

Ecosystem: A system of living organisms interacting with each other and their physical environment.

Element: A unit of natural biological diversity. Elements represent species (or infraspecific taxa), natural communities, or other nontaxonomic biological entities (e.g., migratory species aggregation areas; NatureServe 2002).

Element occurrence: A term used by conservation data centres and NatureServe that refers to an occurrence of an element of biodiversity on the landscape; an area of land and/or water on/in which an element (e.g., species or ecological community) is or was present. An EO has conservation value for the element: is a location important to the conservation of the species or community. For a species, an element occurrence is generally the habitat occupied by a local population. What constitutes an occurrence varies among species. Breeding colonies, breeding ponds, denning sites, and hibernacula are general examples of different types of animal element occurrences. For an ecological community, it may be the area containing a patch of that community type (NatureServe 2002).

Emissions scenario: A plausible representation of the future development of emissions of greenhouse gases and aerosols that are potentially radiatively active, based on certain demographic, technological, or environmental developments.

Endangered: A native species facing imminent extinction or extirpation (COSEWIC 2015B).

Ensemble: A collection of model simulations characterizing a climate prediction or projection. Differences in initial conditions and model formulation result in different evolutions of the modelled system and may give information on uncertainty associated with model error and error in initial conditions in the case of climate forecasts and on uncertainty associated with model error and with internally generated climate variability in the case of climate projections (IPCC 2014).

Exposure: The nature and extent to which a species is exposed to significant climate variation.

Evapotranspiration: The sum of evaporation from the soil and transpiration from plants.

Fen: A wetland fed by surface water, groundwater, or both and characterized by the chemistry of the water, which is neutral or alkaline.

General circulation model: numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and their feedback processes and accounting for all or some of its known properties.

Greenhouse gases: Are gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect.

Monte Carlo simulation: A mathematical technique that generates random variables for modelling risk, or uncertainty of a certain system. The random variables or inputs are modelled on the basis of probability distributions such as normal, log normal, etc.

Not at risk: A wildlife species that has been evaluated and found to be not at risk of extinction given current circumstances (COSEWIC 2015B).

Projection: A potential future evolution of a quantity or set of quantities, often computed using a model; distinguished from prediction by the fact that projections involve assumptions that may or may not be realized so are subject to more uncertainty.

Refugia: Locations and habitats that support populations of organisms that are limited to small fragments of their prior geographic range.

Representative concentration pathways (RCPs): Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover (Moss et al. 2008). *Representative* means that each RCP provides only one of many possible scenarios that would lead to specific radiative forcing characteristics. *Pathway* reflects that not only the long-term concentration levels are of interest but also the trajectory over time to reach that outcome (Moss et al. 2010). RCPs usually refer to the part of the concentration pathway extending up to 2100, for which integrated assessment models produced corresponding emission scenarios. Four RCPs (2.6, 4.5, 6.0, 8.5) are used in the present IPCC Assessment as a basis for the climate predictions and projections (IPCC 2013).

Resilience: Ability of a species or system to absorb a disturbance and continue to develop with similar fundamental function, structure, identity, and feedbacks.

Special concern: A species that may become a threatened or an endangered due to a combination of biological characteristics and identified threats (COSEWIC 2015B).

Species at risk: An extirpated, endangered, or threatened species or species of special concern (COSEWIC 2015B).

Sensitivity: The degree to which a species is affected when exposed to a stress.

Swamp: A wetland type dominated by woody plants often with surface water throughout part of the year.

Threatened: A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction (COSEWIC 2015B).

Vulnerability: The degree to which a species is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007).

Appendix B: Conservation status ranks, basin presence, and Climate Change Vulnerability Index scores.

		Lake basin					Conservation status							
Taxonomic group	**Species**	**Superior**	**Huron**	**Erie**	**Ontario**	**St Lawrence**	**COSEWIC[1]**	**COSSARO[1]**	**Grank[1]**	**Srank[1]**	**CCVI score[2]**	**Confidence[3]**	**Migratory**	**Migr exp[4]**
Amphibian	*Ambystoma maculatum* (Spotted salamander)	●	●	●	●	●	-	-	G5	S4	MV	Mod	-	-
Amphibian	*Anaxyrus fowleri* (Fowler's toad)	-	-	●	-	-	END	END	G5	S2	HV	Mod	-	-
Amphibian	*Desmognathus fuscus* (Northern dusky salamander)	-	-	-	●	-	END	END	G5	S1	HV	Mod	-	-
Amphibian	*Desmognathus ochrophaeus* (Allegheny mountain dusky salamander)	-	-	-	●	-	END	END	G5	S1	HV	Mod	-	-
Amphibian	*Hemidactylium scutatum* (Four-toed salamander)	-	●	●	●	●	-	-	G5	S4	MV	Mod	-	-
Amphibian	*Lithobates palustris* (Pickerel frog)	-	●	●	●	●	NAR	NAR	G5	S4	MV	Low	-	-
Amphibian	*Lithobates septentrionalis* (Mink frog)	●	●	●	●	●	-	-	G5	S5	LV	Low	-	-
Amphibian	*Necturus maculosus* (Mudpuppy)	●	●	●	●	●	NAR	NAR	G5	S4	LV	VH	-	-
Amphibian	*Notophthalmus viridescens viridescens* (Red-spotted newt)	●	●	●	●	●	-	-	G5T5	S5	LV	VH	-	-
Amphibian	*Pseudacris crucifer* (Spring peeper)	●	●	●	●	●	-	-	G5	S5	MV	Low	-	-
Amphibian	*Pseudacris maculata* (Boreal chorus frog)	●	-	-	-	-	-	-	G5	S5	MV	Mod	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Amphibian	*Pseudacris triseriata* pop. 1 (Western chorus frog, Great Lakes/St. Lawrence - Canadian Shield population)	-	●	●	●	●	THR	NAR	G5TNR	S3	MV	Low	-	-
Amphibian	*Pseudacris triseriata* pop. 2 (Western chorus frog, Carolinian population)	-	●	●	●	-	NAR	NAR	G5TNR	S4	MV	High	-	-
Bird	*Aix sponsa* (Wood duck)	●	●	●	●	●	-	-	G5	S5	LV	VH	-	-
Bird	*Anas discors* (Blue-winged teal)	●	●	●	●	●	-	-	G5	S4	LV	VH	-	-
Bird	*Anas rubripes* (American black duck)	●	●	●	●	●	-	-	G5	S4	LV	VH	-	-
Bird	*Antrostomus vociferus* (Eastern whip-poor-will)	●	●	●	●	●	THR	THR	G5	S4B	LV	Mod	●	H
Bird	*Asio flammeus* (Short-eared owl)	●	●	●	●	●	SC	SC	G5	S4B	LV	VH	-	-
Bird	*Aythya collaris* (Ring-necked duck)	●	●	●	●	●	-	-	G5	S5	LV	VH	-	-
Bird	*Buteo lineatus* (Red-shouldered hawk)	●	●	●	●	●	NAR	NAR	G5	S4B	LV	VH	-	-
Bird	*Butorides virescens* (Green heron)	-	●	●	●	●	-	-	G5	S4B	LV	VH	-	-
Bird	*Cathartes aura* (Turkey vulture)	●	●	●	●	●	-	-	G5	S5B	LV	VH	-	-
Bird	*Chaetura pelagica* (Chimney swift)	●	●	●	●	●	THR	THR	G5	S4B	LV	Low	●	H
Bird	*Charadrius melodus* (Piping plover)	-	●	●	●	-	END	END	G3	S1B	HV	High	●	H
Bird	*Colinus virginianus* (Northern bobwhite)	-	-	●	-	-	END	END	G5	S1	LV	VH	-	-
Bird	*Contopus cooperi* (Olive-sided flycatcher)	●	●	-	●	●	THR	SC	G4	S4B	LV	VH	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Bird	*Coturnicops noveboracensis* (Yellow rail)	●	●	-	●	●	SC	SC	G4	S4B	MV	Low	-	-
Bird	*Dolichonyx oryzivorus* (Bobolink)	●	●	●	●	●	THR	THR	G4	S4B	LV	VH	●	H
Bird	*Empidonax virescens* (Acadian flycatcher)	-	●	●	●	-	END	END	G5	S2S3B	LV	Mod	●	H
Bird	*Euphagus carolinus* (Rusty blackbird)	●	●	-	●	●	SC	NAR	G4	S4B	LV	VH	-	-
Bird	*Falco peregrinus* (Peregrine falcon)	●	●	●	●	●	SC	SC	G4	S3B	LV	VH	●	M
Bird	*Hirundo rustica* (Barn swallow)	●	●	●	●	●	THR	THR	G5	S4B	LV	VH	●	M
Bird	*Icteria virens* (Yellow-breasted chat)	-	-	●	-	-	END	END	G5	S1B	LV	VH	●	H
Bird	*Ixobrychus exilis* (Least bittern)	-	●	●	●	●	THR	THR	G5	S4B	LV	VH	-	-
Bird	*Lanius ludovicianus* (Loggerhead shrike)	-	●	-	●	●	END	END	G4	S2B	LV	VH	●	M
Bird	*Melanerpes erythrocephalus* (Red-headed woodpecker)	-	●	●	●	●	THR	SC	G5	S4B	LV	VH	-	-
Bird	*Meleagris gallopavo* (Wild turkey)	-	●	●	●	●	-	-	G5	S5	LV	VH	-	-
Bird	*Parkesia motacilla* (Louisiana waterthrush)	-	●	●	●	●	THR	THR	G5	S3B	HV	Low	●	H
Bird	*Perisoreus canadensis* (Gray jay)	●	●	-	●	●	-	-	G5	S5	MV	VH	-	-
Bird	*Podilymbus podiceps* (Pied-billed grebe)	●	●	●	●	●	-	-	G5	S4	LV	VH	-	-
Bird	*Protonotaria citrea* (Prothonotary warbler)	-	●	●	●	-	END	END	G5	S1B	MV	Mod	●	H
Bird	*Rallus elegans* (King rail)	-	●	●	●	●	END	END	G4	S2B	MV	VH	-	-
Bird	*Setophaga cerulea* (Cerulean	-	●	●	●	●	END	THR	G4	S3B	MV	VH	●	H

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
	warbler)													
Bird	*Setophaga citrina* (Hooded warbler)	-	●	●	●	-	NAR	NAR	G5	S4B	LV	VH	-	-
Bird	*Setophaga discolor* (Prairie warbler)	-	●	●	●	●	NAR	NAR	G5	S3B	LV	VH	-	-
Bird	*Setophaga kirtlandii* (Kirtland's warbler)	-	●	-	-	●	END	END	G1	S1B	LV	VH	●	M
Bird	*Sturnella magna* (Eastern meadowlark)	●	●	●	●	●	THR	THR	G5	S4B	LV	Low	-	-
Bird	*Tyto alba* (Barn owl)	-	-	●	-	-	END	END	G5	S1	LV	VH	-	-
Bird	*Vermivora chrysoptera* (Golden-winged warbler)	-	●	●	●	●	THR	SC	G4	S4B	LV	VH	●	H
Bryophyte	*Amblyodon dealbatus* (Short-toothed hump moss)	-	●	-	-	-	-	-	G3G5	S1	MV	Mod	-	-
Bryophyte	*Aulacomnium acuminatum* (Acutetip groove moss)	●	-	-	-	-	-	-	G4G5	S3	HV	Mod	-	-
Bryophyte	*Bryoandersonia illecebra* (Spoon-leaved moss)	-	●	●	●	-	END	END	G5	S2	HV	Low	-	-
Bryophyte	*Buxbaumia aphylla* (Brown shield moss)	●	●		●	●	-	-	G4G5	S2S3	LV	VH	-	-
Bryophyte	*Fissidens exilis* (Pygmy pocket moss)	-	-	●	-	-	NAR	SC	G3G4	S2	MV	VH	-	-
Bryophyte	*Marsupella sphacelata* (Speckled rustwort)	-	●	-	●	●	-	-	G5	S1S2	MV	High	-	-
Bryophyte	*Meesia uliginosa* (Capillary thread moss)	●	●	-	-	-	-	-	G5	S3	MV	High	-	-

		Lake basin					Conservation status							
Taxonomic group	**Species**	**Superior**	**Huron**	**Erie**	**Ontario**	**St Lawrence**	**COSEWIC[1]**	**COSSARO[1]**	**Grank[1]**	**Srank[1]**	**CCVI score[2]**	**Confidence[3]**	**Migratory**	**Migr exp[4]**
Bryophyte	*Mielichhoferia mielichhoferiana* (Alpine copper moss)	●	-	-	-	-	-	-	G4	S1	HV	Mod	-	-
Bryophyte	*Mnium thomsonii* (Thomson's leafy moss)	●	●	-	-	-	-	-	G5	S3	LV	Mod	-	-
Bryophyte	*Oncophorus virens* (Green spur moss)	●	●	-	-	-	-	-	G5	S3	MV	Low	-	-
Bryophyte	*Porella pinnata* (Pinnate scalewort)	-	●	-	●	●	-	-	G5	S3?	LV	Low	-	-
Bryophyte	*Rhytidiadelphus subpinnatus* (Square gooseneck moss)	●	●	-	●	●	-	-	G5	S2	MV	Low	-	-
Bryophyte	*Sphagnum cuspidatum* (Feathery peat moss)	●	●	●	●	●	-	-	G5	S3	MV	Low	-	-
Bryophyte	*Sphagnum platyphyllum* (Flat-leaved peat moss)	●	●	-	●	-	-	-	G5	S2	LV	Mod	-	-
Bryophyte	*Splachnum rubrum* (Brilliant red dung moss)	●	●	-	-	●	-	-	G5	S2	MV	VH	-	-
Bryophyte	*Syntrichia cainii* (Cain's screw moss)	-	●	-	-	-	-	-	G1	S1	MV	Low	-	-
Bryophyte	*Tetraplodon mnioides* (Smooth-margin nitrogen moss)	●	-	-	-	-	-	-	G5	S2	MV	Mod	-	-
Bryophyte	*Tetrodontium brownianum* (Brown's four-toothed moss)	●	●	-	-	●	-	-	G3G4	S1	LV	Low	-	-
Bryophyte	*Tortula porteri* (Porter's screw moss)	-	-	●	●	-	NAR		G3?	S2	HV	VH	-	-
Fish	*Acipenser fulvescens* pop. 2 (Lake sturgeon, southern Hudson Bay/James Bay population)	●	-	-	-	-	SC	SC	G3G4TNR	S3	HV	Mod	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Fish	*Acipenser fulvescens* pop. 3 (Lake sturgeon, Great Lakes-upper St. Lawrence River population)	●	●	●	●	●	THR	THR	G3G4TNR	S2	HV	Mod	-	-
Fish	*Ammocrypta pellucida* (Eastern sand darter)	-	●	●	●	-	THR	END	G4	S2	HV	High	-	-
Fish	*Clinostomus elongatus* (Redside dace)	-	●	●	●	-	END	END	G3G4	S2	EV	VH	-	-
Fish	*Coregonus zenithicus* (Shortjaw cisco)	●	●	-	-	●	THR	THR	G3	S2	EV	VH	-	-
Fish	*Erimyzon sucetta* (Lake chubsucker)	-	●	●	●	-	END	THR	G5	S2	MV	Mod	-	-
Fish	*Esox americanus vermiculatus* (Grass pickerel)	-	●	●	●	●	SC	SC	G5T5	S3	MV	VH	-	-
Fish	*Exoglossum maxillingua* (Cutlip minnow)	-	-	-	-	●	SC	THR	G5	S1S2	LV	Low	-	-
Fish	*Fundulus notatus* (Blackstripe topminnow)	-	●	●	-	-	SC	SC	G5	S2	LV	VH	-	-
Fish	*Ichthyomyzon fossor* (Northern brook lamprey)	●	●	●	●	●	SC	SC	G4	S3	HV	VH	-	-
Fish	*Lepisosteus oculatus* (Spotted gar)	-	-	●	●	-	END	END	G5	S1	HV	Mod	-	-
Fish	*Lepomis gulosus* (Warmouth)	-	-	●	-	-	END	END	G5	S1	LV	Low	-	-
Fish	*Minytrema melanops* (Spotted sucker)	-	●	●	-	-	SC	SC	G5	S2	LV	Mod	-	-
Fish	*Moxostoma carinatum* (River redhorse)	-	-	●	●	●	SC	SC	G4	S2	MV	VH	-	-
Fish	*Moxostoma duquesnei* (Black redhorse)	-	●	●	●	-	THR	THR	G5	S2	HV	Mod	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Fish	*Notropis photogenis* (Silver shiner)	-	-	●	●	-	THR	THR	G5	S2S3	MV	Mod	-	-
Fish	*Noturus stigmosus* (Northern madtom)	-		●	-	-	END	END	G3	S1	MV	Low	-	-
Fish	*Opsopoeodus emiliae* (Pugnose minnow)	-	-	●	-	-	THR	THR	G5	S2	MV	VH	-	-
Fish	*Percina copelandi* (Channel darter)	-	-	●	●	●	THR	THR	G4	S2	HV	Mod	-	-
Insect/spider	*Aeshna juncea* (Sedge darner)	●	-	-	-	-	-	-	G5	S3?	MV	Low	-	-
Insect/spider	*Amphiagrion saucium* (Eastern red damsel)	-	●	●	●	●	-	-	G5	S4	LV	Low	-	-
Insect/spider	*Atrytonopsis hianna* (Dusted Skipper)	-	●	-	-	-	-	-	G4G5	S1	EV	Low	-	-
Insect/spider	*Bombus affinis* (Rusty-patched bumble bee)	-	●	●	●	-	END	END	G1	S1	LV	Low	-	-
Insect/spider	*Callophrys lanoraieensis* (Bog elfin)	-	-	-	-	●	-	-	G3G4	S1	HV	VH	-	-
Insect/spider	*Erora laeta* (Early hairstreak)	-	●	-	●	●	-	-	GU	S2	LV	VH	-	-
Insect/spider	*Erynnis martialis* (Mottled duskywing)	-	●	●	●	●	END	END	G3	S2	MV	VH	-	-
Insect/spider	*Gomphaeschna furcillata* (Harlequin darner)	-	●	●	●	●	-	-	G5	S3	MV	VH	-	-
Insect/spider	*Lestes eurinus* (Amber-winged spreadwing)	-	●	●	●	●	-	-	G5	S3	LV	VH	-	-
Insect/spider	*Nannothemis bella* (Elfin skimmer)	-	●	●	●	●	-	-	G4	S4	LV	Mod	-	-
Insect/spider	*Oarisma garita* (Garita skipperling)	-	●	-	-	-	-	-	G5	S1	MV	VH	-	-
Insect/spider	*Pieris virginiensis* (West Virginia white)	●	●	●	●	●	-	SC	G3?	S3	MV	VH	-	-

		Lake basin					Conservation status							
Taxonomic group	**Species**	**Superior**	**Huron**	**Erie**	**Ontario**	**St Lawrence**	**COSEWIC[1]**	**COSSARO[1]**	**Grank[1]**	**Srank[1]**	**CCVI score[2]**	**Confidence[3]**	**Migratory**	**Migr exp[4]**
Insect/spider	*Rhionaeschna mutata* (Spatterdock darner)	-	-	●	-	-	-	-	G4	S2	LV	VH	-	-
Insect/spider	*Sphodros niger* (Black purse web spider)	-	-	●	●	-	-	-	G4G5	S3	LV	VH	-	-
Insect/spider	*Trimerotropis huroniana* (Lake Huron grasshopper)	●	●	-	-	-	THR	THR	G2G3	S2	HV	Low	-	-
Insect/spider	*Williamsonia fletcheri* (Ebony boghaunter)	-	●	-	●	●	-	-	G4	S2	LV	VH	-	-
Lichen	*Ahtiana aurescens* (Eastern candlewax lichen)	●	-	-	-	-	-	-	G3G5	S3	MV	Mod	-	-
Lichen	*Anaptychia crinalis* (Hanging fringed lichen)	●	●	●	●	●	-	-	GU	S3	MV	VH	-	-
Lichen	*Arthrorhaphis alpina* (Alpine dot lichen)	●	-	-	-	-	-	-	G5	S1?	HV	Low	-	-
Lichen	*Bryoria pikei* (Pike's horsehair lichen)	●	-	-	-	-	-	-	G5	S4	HV	VH	-	-
Lichen	*Cetraria laevigata* (Pin-striped Icelandmoss lichen)	●	-	-	-	-	-	-	G5	S2S3	MV	Low	-	-
Lichen	*Flavocetraria nivalis* (Crinkled snow lichen)	●	-	-	-	-	-	-	G5	S4S5	HV	Mod	-	-
Lichen	*Heppia adglutinata* (Soil ruby lichen)	-	●	-	●	●	-	-	G4G5	S1S2	LV	Low	-	-
Lichen	*Leptogium corticola* (Blistered jellyskin lichen)	●	●	-	-	●	-	-	G3G5	S2	MV	VH	-	-
Lichen	*Leptogium rivulare* (Flooded jellyskin)	-	●	-	●	●	SC	NAR	G3G5	S3	MV	VH	-	-
Lichen	*Lobaria pulmonaria* (Lungwort lichen)	●	●	-	●	●	-	-	G4G5	S4	MV	Low	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Lichen	*Parmotrema hypotropum* (Southern powdered ruffle lichen)	-	-	●	-	-	-	-	G5?	S2	LV	Mod	-	-
Lichen	*Physconia subpallida* (Pale-bellied frost lichen)	-	-	-	●	●	END	END	GNR	S2S3	LV	Low	-	-
Lichen	*Pseudocyphellaria holarctica* (Yellow specklebelly lichen)	●	-	-	-	-	-	-	GNR	S1	HV	VH	-	-
Lichen	*Punctelia appalachensis* (Appalachian speckled shield lichen)	●	●	-	-	●	-	-	G3G4	S2	MV	VH	-	-
Lichen	*Sticta beauvoisii* (Fingered moon lichen)	●	-	-	-	●	-	-	G3G4	S1	HV	Low	-	-
Lichen	*Teloschistes chrysophthalmus* pop. 1 (Golden-eye lichen, Great Lakes population)	-	-	-	●	-	END		G4G5TNR	S1	LV	VH	-	-
Lichen	*Thyrea confusa* (Jelly-strap lichen)	-	●	●	●	●	-	-	G3G5	S2	MV	VH	-	-
Lichen	*Usnea longissima* (Methuselah's beard lichen)	●	-	-	-	-	-	-	G4	S2	HV	Low	-	-
Lichen	*Xanthoria parietina* (Maritime sunburst lichen)	-	●	●	●	●	-	-	G3G5	SNA	LV	VH	-	-
Mammal	*Alces americanus* (Moose)	●	●	-	●	●	-	-	G5	S5	MV	Mod	-	-
Mammal	*Didelphis virginiana* (Virginia opossum)	-	●	●	●	●	-	-	G5	S4	LV	VH	-	-
Mammal	*Lepus americanus* (Snowshoe hare)	●	●	●	●	●	-	-	G5	S5	MV	VH	-	-
Mammal	*Lynx canadensis* (Canada lynx)	●	●	-	●	●	-	-	G5	S5	MV	VH	-	-
Mammal	*Microtus pinetorum* (Woodland vole)	-	●	●	●	-	SC	SC	G5	S3?	LV	Low	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Mammal	*Myotis septentrionalis* (Northern myotis)	●	●	●	●	●	END	END	G1G2	S1S2	MV	Mod	-	-
Mammal	*Perimyotis subflavusi* (Tricolored bat)	●	●	●	●	●	END	END	G2G3	S3?	LV	VH	-	-
Mammal	*Rangifer tarandus* (Caribou, boreal pop.)	●	-	-	-	-	THR	THR	G5TNR	S4	HV	Mod	-	-
Mammal	*Scalopus aquaticus* (Eastern mole)	-	-	●	-	-	SC	SC	G5	S2	LV	VH	-	-
Mammal	*Taxidea taxus* (American badger)	-	●	●	-	-	END SC	END	G5	S2	MV	VH	-	-
Mammal	*Urocyon cinereoargenteus* (Gray fox)	●	-	●	-	-	THR	THR	G5	S1	LV	VH	-	-
Mollusc	*Anguispira kochi* (Banded globe)	-	-	●	-	-	-	-	G5	S2S3	MV	VH	-	-
Mollusc	*Epioblasma torulosa rangiana* (Northern riffleshell)	-	●	●	-	-	END	END	G2T2	S1	HV	Mod	-	-
Mollusc	*Epioblasma triquetra* (Snuffbox)	-	●	●	-	-	END	END	G3	S1	HV	Mod	-	-
Mollusc	*Ligumia nasuta* (Eastern pondmussel)	-	-	●	●	●	END	END	G4	S1	MV	Mod	-	-
Mollusc	*Mesodon clausus* (Yellow globelet)	-	-	●	-	-	-	-	G5	S1	MV	High	-	-
Mollusc	*Simpsonaias ambigua* (Salamander mussel)	-	-	●	-	-	END	END	G3	S1	EV	Mod	-	-
Mollusc	*Villosa fabalis* (Rayed bean)	-	-	●	-	-	END	END	G2	S1	HV	Low	-	-
Reptile	*Chelydra serpentina* (Snapping turtle)	●	●	●	●	●	THR	THR	G5	S3	LV	VH	-	-
Reptile	*Clemmys guttata* (Spotted turtle)	-	●	●	●	●	END	END	G5	S2	MV	Mod	-	-
Reptile	*Coluber constrictor foxii* (Blue racer)	-	-	●	-	-	END	END	G5T5	S1	MV	VH	-	-
Reptile	*Emydoidea blandingii* (Blanding's turtle)	-	●	●	●	●	END	THR	G4	S3	MV	VH	-	-
Reptile	*Glyptemys insculpta* (Wood turtle)	●	●	-	●	●	THR	END	G3	S2	MV	VH	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Reptile	*Graptemys geographica* (Northern map turtle)	-	●	●	●	●	SC	SC	G5	S3	LV	Mod	-	-
Reptile	*Nerodia sipedon insularum* (Lake Erie watersnake)	-	-	●	-	-	SC	SC	G5T2	S2	LV	VH	-	-
Reptile	*Opheodrys vernalis* (Smooth greensnake)	●	●	●	●	●	-	-	G5	S4	LV	Low	-	-
Reptile	*Pantherophis gloydi* pop. 1 (Eastern foxsnake, Georgian Bay population)	-	●	-	-	-	END	THR	G3TNR	S3	LV	Low	-	-
Reptile	*Pantherophis gloydi* pop. 2 (Eastern foxsnake, Carolinian population)	-	●	●	-	-	END	END	G3TNR	S2	MV	Mod	-	-
Reptile	*Pantherophis spiloides* pop. 1 (Eastern ratsnake, Great Lakes - St. Lawrence population)	-	-	-	●	●	THR	THR	G5T3	S3	LV	VH	-	-
Reptile	*Pantherophis spiloides* pop. 2 (Eastern ratsnake, Carolinian population)	-	-	●	●	-	END	END	G5T1	S1	MV	Mod	-	-
Reptile	*Plestiodon fasciatus* pop. 1 (Common five-lined skink, Carolinian population)	-	●	●	●	-	END	END	G5T2	S2	HV	VH	-	-
Reptile	*Plestiodon fasciatus* pop. 2 (Common five-lined skink, southern Shield population)	-	●	-	●	●	SC	SC	G5T3	S3	LV	VH	-	-
Reptile	*Regina septemvittata* (Queensnake)	-	●	●	●	-	END	END	G5	S2	MV	Mod	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Reptile	*Thamnophis butleri* (Butler's gartersnake)	-	●	●	-	-	END	END	G4	S2	MV	Mod	-	-
Vascular plant	*Acer saccharum* (Sugar maple)	●	●	●	●	●	-	-	G5	S5	LV	VH	-	-
Vascular plant	*Adenocaulon bicolor* (Pathfinder)	-	●	-	-	-	-	-	G5	S1	MV	VH	-	-
Vascular plant	*Adoxa moschatellina* (Muskroot)	●	-	-	-	-	-	-	G5	S1	MV	VH	-	-
Vascular plant	*Aplectrum hyemale* (Puttyroot)		●	●	●	●	-	-	G5	S2	MV	Mod	-	-
Vascular plant	*Asplenium ruta-muraria* (Wallrue spleenwort)	-	●	-	-	-	-	-	G5	S2	MV	Mod	-	-
Vascular plant	*Asplenium scolopendrium* var. *americanum* (American hart's-tongue fern)	-	●	-	●	-	SC	SC	G4T3	S3	HV	Mod	-	-
Vascular plant	*Astragalus neglectus* (Neglected milk-vetch)	-	●	●	●	●	-	-	G4	S3	LV	Low	-	-
Vascular plant	*Aureolaria pedicularia* (Fern-leaved false foxglove)	-	●	●	●	-	-	-	G5	S2?	MV	Mod	-	-
Vascular plant	*Azolla cristata* (Eastern mosquito fern)	-	-	-	●	●	-	-	G5	S1S2	LV	High	-	-
Vascular plant	*Bartonia paniculata* spp. *paniculata* (Branched bartonia)	-	●	-	-	-	THR	THR	G5T5	S2	MV	Mod	-	-
Vascular plant	*Botrychium ascendens* (Upswept moonwort)	●	-	-	-	-	-	-	G3	S1S2	MV	Low	-	-
Vascular plant	*Botrychium pallidum* (Pale moonwort)	●	-	-	-	-	-	-	G3	S1S2	MV	VH	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Vascular plant	*Botrychium spathulatum* (Spatulate moonwort)	●	-	-	-	●	-	-	G3	S2S3	LV	VH	-	-
Vascular plant	*Bouteloua curtipendula* (Side-oats grama)	-	-	●	●	●	-	-	G5	S2	LV	Low	-	-
Vascular plant	*Carex aggregata* (Glomerate sedge)	-	-	●	-	-	-	-	G5	S1	MV	VH	-	-
Vascular plant	*Carex alata* (Broad-winged sedge)	-	-	●	-	-	-	-	G5	S1	HV	High	-	-
Vascular plant	*Carex atratiformis* (Black sedge)	●	-	-	-	-	-	-	G5	S2S3	MV	High	-	-
Vascular plant	*Carex juniperorum* (Juniper sedge)	-	-	●	●	-	END	END	G3	S1	MV	Mod	-	-
Vascular plant	*Carex loliacea* (Ryegrass sedge)	●	-	-	-	-	-	-	G5	S1S2	MV	Mod	-	-
Vascular plant	*Carex lupuliformis* (False Hop sedge)	-	●	●	-	-	END	END	G4	S1	HV	VH	-	-
Vascular plant	*Carex nigromarginata* (Black-edged sedge)	-	-	●	-	-	-	-	G5	S1	HV	VH	-	-
Vascular plant	*Carex schweinitzii* (Schweinitz's sedge)	-	●	●	●	-	-	-	G3G4	S3	MV	VH	-	-
Vascular plant	*Carex wiegandii* (Wiegand's sedge)	●	-	-	-	-	-	-	G4	S1	MV	VH	-	-
Vascular plant	*Carya laciniosa* (Shellbark hickory)	-	-	●	●	-	-	-	G5	S3	LV	Mod	-	-
Vascular plant	*Castanea dentata* (American chestnut)	-	●	●	-	-	END	END	G4	S1S2	MV	Mod	-	-
Vascular plant	*Celtis tenuifolia* (Dwarf hackberry)	-	●	●	●		THR	THR	G5	S2	LV	VH	-	-
Vascular plant	*Chamaenerion latifolium* (River beauty)	●	-	-	-	-	-	-	G5	S4	EV	VH	-	-
Vascular plant	*Chimaphila maculata* (Spotted wintergreen)	-	-	●	●	-	END	THR	G5	S2	MV	High	-	-
Vascular plant	*Cirsium pitcheri* (Pitcher's thistle)	●	●	-	-	-	SC	THR	G2G3	S2	HV	Mod	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Vascular plant	*Conioselinum chinense* (Chinese hemlock-parsley)	-	●	●	-	-	-	-	G5	S2	HV	Low	-	-
Vascular plant	*Coptidium lapponicum* (Lapland buttercup)	●	-	-	-	-	-	-	G5	S5?	MV	VH	-	-
Vascular plant	*Cornus florida* (Flowering dogwood)	-	●	●	●	-	END	END	G5	S2?	MV	VH	-	-
Vascular plant	*Cuscuta cephalanthi* (Buttonbush dodder)	-	-	●	●	●	-	-	G5	S2	MV	VH	-	-
Vascular plant	*Cypripedium arietinum* (Ram's-head lady's-slipper)	●	●	●	●	●	-	-	G3	S3	MV	VH	-	-
Vascular plant	*Cypripedium candidum* (Small white lady's-slipper)	-	-	●	●	-	END	END	G4	S1	HV	High	-	-
Vascular plant	*Cypripedium passerinum* (Sparrow's-egg lady's-slipper)	●	-	-	-	-	-	-	G5	S4	MV	VH	-	-
Vascular plant	*Cystopteris laurentiana* (Laurentian bladder fern)	●	●	-	-	-	-	-	G3	S3	LV	VH	-	-
Vascular plant	*Cystopteris montana* (Mountain bladder fern)	●	-	-	-	-	-	-	G5	S1	MV	Mod	-	-
Vascular plant	*Draba aurea* (Golden draba)	●	-	-	-	-	-	-	G5	S5	HV	VH	-	-
Vascular plant	*Dryas drummondii* (Yellow mountain-avens)	●	-	-	-	-	-	-	G5	S1	EV	Mod	-	-
Vascular plant	*Eleocharis equisetoides* (Horsetail spikerush)	-	-	●	-	-	END	END	G4	S1	HV	Mod	-	-
Vascular plant	*Eleocharis geniculata* (Bent	-	-	●	-	-	END	END	G5	S1	EV	VH	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
	spikerush)													
Vascular plant	*Elymus lanceolatus* ssp. *psammophilus* (Great Lakes wild rye)	-	●	-	-	-	-	-	G5T3	S3	MV	VH	-	-
Vascular plant	*Enemion biternatum* (False rue-anemone)	-	●	●	-	-	THR	THR	G5	S2	MV	VH	-	-
Vascular plant	*Erigeron hyssopifolius* (Daisy fleabane)	●	●	-	-	-	-	-	G5	S5	HV	Mod	-	-
Vascular plant	*Euphorbia commutata* (Tinted woodland spurge)	-	●	●	●	●	-	-	G5	S1	MV	Mod	-	-
Vascular plant	*Fraxinus nigra* (Black ash)	●	●	●	●	●	-	-	G5	S4	MV	Mod	-	-
Vascular plant	*Fraxinus profunda* (Pumpkin ash)	-	●	●	●	-	-	-	G4	S2?	MV	High	-	-
Vascular plant	*Gentiana alba* (White prairie pentian)	-	-	●	-	-	END	END	G4	S1	MV	VH	-	-
Vascular plant	*Gratiola quartermaniae* (Limestone hedge-hyssop)	-	-	-	●	-	-	-	G3	S2	HV	VH	-	-
Vascular plant	*Gymnocarpium continentale* (Nahanni oak fern)	●	-	-	-	-	-	-	G4	S3	LV	Mod	-	-
Vascular plant	*Hibiscus moscheutos* (Swamp rose mallow)	-	-	●	●	-	SC	SC	G5	S3	LV	Mod	-	-
Vascular plant	*Hudsonia tomentosa* (Woolly beach-heath)	●	●	-	-	●	-	-	G5	S3	LV	Low	-	-
Vascular plant	*Hydrastis canadensis* (Goldenseal)	-	●	●	-	-	THR	THR	G3G4	S2	MV	High	-	-
Vascular plant	*Hypericum prolificum* (Shubby St. John's-wort)	-	-	●	●	-	-	-	G5	S2	LV	Low	-	-
Vascular plant	*Iris brevicaulis* (Short-stemmed iris)	-	-	●	-	-	-	-	G4	S1	MV	VH	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Vascular plant	*Iris lacustris* (Dwarf lake iris)	-	●	-	-	-	SC	SC	G3	S3	MV	VH	-	-
Vascular plant	*Isoetes engelmannii* (Engelmann's quillwort)	-	●	-	●	-	END	END	G4	S1	LV	Low	-	-
Vascular plant	*Isoetes tuckermanii* (Tuckerman's quillwort)	-	●	-	●	-	-	-	G4G5	S2S3	LV	VH	-	-
Vascular plant	*Isotria medeoloides* (Small whorled pogonia)	-	-	●	-	-	END	END	G2?	S1	HV	VH	-	-
Vascular plant	*Juglans cinerea* (Butternut)	-	●	●	●	●	END	END	G4	S2?	MV	VH	-	-
Vascular plant	*Justicia americana* (American water-willow)	-	-	●	●	●	THR	THR	G5	S2	LV	Mod	-	-
Vascular plant	*Lespedeza virginica* (Slender bush-clover)	-	-	●	-	-	END	END	G5	S1	MV	Low	-	-
Vascular plant	*Linum striatum* (Ridged yellow flax)	-	●	-	-	-	-	-	G5	S1	LV	Mod	-	-
Vascular plant	*Liparis liliifolia* (Purple twayblade)	-	●	●	●	●	THR	THR	G5	S2S3	LV	VH	-	-
Vascular plant	*Lupinus perennis* (Sundial lupine)	-	●	●	●	-	-	-	G5	S2S3	LV	Low	-	-
Vascular plant	*Magnolia acuminata* (Cucumber magnolia)	-	-	●	●	-	END	END	G5	S2	MV	VH	-	-
Vascular plant	*Malaxis paludosa* (Bog adder's-mouth)	●	-	-	-	●	-	-	G4	S1S2	HV	Mod	-	-
Vascular plant	*Moehringia macrophylla* (Large-leaved sandwort)	●	-	-	-	-	-	-	G5	S2	MV	Mod	-	-
Vascular plant	*Muhlenbergia richardsonis* (Mat muhly)	-	●	●	-	-	-	-	G5	S3	MV	Mod	-	-
Vascular plant	*Nelumbo lutea* (American lotus)	-	●	●	-	-	-	-	G4	S2S3	LV	VH	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Vascular plant	*Nyssa sylvatica* (Black gum)	-	-	●	●	-	-	-	G5	S3	LV	Low	-	-
Vascular plant	*Oplopanax horridus* (Devil's club)	●	-	-	-	-	-	-	G4G5	S1	EV	VH	-	-
Vascular plant	*Opuntia fragilis* (Brittle prickly-pear)	-	-	-	●	-	-	-	G4G5	S3	LV	VH	-	-
Vascular plant	*Orobanche fasciculata* (Clustered broomrape)	-	●	-	-	-	-	-	G4	SH	MV	High	-	-
Vascular plant	*Oxytropis splendens* (Showy locoweed)	-	-	-	-	-	-	-	G5	S3	MV	Mod	-	-
Vascular plant	*Peltandra virginica* (Green arrow arum)	-	●	●	●	●	-	-	G5	S3	LV	VH	-	-
Vascular plant	*Phacelia franklinii* (Franklin's phacelia)	●	-	-	-	-	-	-	G5	S2	LV	VH	-	-
Vascular plant	*Phacelia purshii* (Miami-mist)	-	-	●	-	-	-	-	G5	S1	MV	VH	-	-
Vascular plant	*Picea glauca* (White spruce)	●	●	●	●	●	-	-	G5	S5	LV	VH	-	-
Vascular plant	*Picea rubens* (Red spruce)	-	-	-	-	●	-	-	G5	S3	MV	Mod	-	-
Vascular plant	*Pinus rigida* (Pitch pine)	-	-	-	-	●	-	-	G5	S2?	LV	VH	-	-
Vascular plant	*Pinus strobus* (Eastern white pine)	●	●	●	●	●	-	-	G5	S5	LV	VH	-	-
Vascular plant	*Plantago cordata* (Heart-leaved plantain)	-	●	-	-	-	END	END	G4	S1	MV	Mod	-	-
Vascular plant	*Platanthera grandiflora* (Large purple fringed orchid)	-	-	-	-	●	-	-	G5	S1	MV	Low	-	-
Vascular plant	*Platanthera leucophaea* (Eastern prairie fringed orchid)	-	●	●	●	●	END	END	G2G3	S2	HV	Low	-	-
Vascular plant	*Podostemum ceratophyllum* (Horn-leaved riverweed)	-	-	-	●	●	-	-	G5	S2	LV	Low	-	-

		Lake basin					Conservation status							
Taxonomic group	**Species**	**Superior**	**Huron**	**Erie**	**Ontario**	**St Lawrence**	**COSEWIC[1]**	**COSSARO[1]**	**Grank[1]**	**Srank[1]**	**CCVI score[2]**	**Confidence[3]**	**Migratory**	**Migr exp[4]**
Vascular plant	*Polygala incarnata* (Pink milkwort)	-	-	●	-	-	END	END	G5	S1	MV	VH	-	-
Vascular plant	*Polystichum braunii* (Braun's holly fern)	●	●	-	●	●	-	-	G5	S3	LV	VH	-	-
Vascular plant	*Populus heterophylla* (Swamp cottonwood)	-	-	●	-	-	-	-	G5	S1	MV	VH	-	-
Vascular plant	*Potamogeton hillii* (Hill's pondweed)	-	●	●	●	●	SC	SC	G3	S2S3	MV	VH	-	-
Vascular plant	*Ptelea trifoliata* (Common hoptree)	-	-	●	●	-	SC	SC	G5	S3	LV	VH	-	-
Vascular plant	*Pterospora andromedea* (Woodland pinedrops)	●	●	-	●	●	-	-	G5	S2	MV	VH	-	-
Vascular plant	*Pyrola grandiflora* (Arctic pyrola)	●	-	-	-	-	-	-	G5	S4	EV	VH	-	-
Vascular plant	*Quercus ellipsoidalis* (Northern pin oak)	-	-	●	-	-	-	-	G5	S3	LV	Low	-	-
Vascular plant	*Quercus ilicifolia* (Bear oak)	-	-	-	●	-	-	-	G5	S1	LV	VH	-	-
Vascular plant	*Quercus muehlenbergii* (Chinquapin oak)	-	●	●	●	●	-	-	G5	S4	LV	Low	-	-
Vascular plant	*Rhododendron canadense* (Rhodora)	-	-	-	-	●	-	-	G5	S1	HV	Low	-	-
Vascular plant	*Rotala ramosior* (Lowland toothcup)	-	-	-	●	-	THR	END	G5	S1	LV	Mod	-	-
Vascular plant	*Sassafras albidum* (Sassafras)	-	●	●	●	-	-	-	G5	S4	LV	VH	-	-
Vascular plant	*Saxifraga oppositifolia* (Purple mountain saxifrage)	●	-	-	-	-	-	-	G5	S1	EV	VH	-	-
Vascular plant	*Saxifraga paniculata* (Encrusted saxifrage)	●	-	-	-	●	-	-	G5	S4	HV	Mod	-	-
Vascular plant	*Scleria verticillata* (Low nutrush)	-	●	●	●	-	-	-	G5	S3	MV	High	-	-

Taxonomic group	Species	Lake basin					Conservation status							
		Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Vascular plant	*Sida hermaphrodita* (Virginia mallow)	-	-	●	●	-	END	END	G3	S1	MV	VH	-	-
Vascular plant	*Silene acaulis* (Moss campion)	●	-	-	-	-	-	-	G5	S1	EV	VH	-	-
Vascular plant	*Smilax rotundifolia* (Round-leaved greenbrier)	-	-	●	●	-	THR	THR	G5	S2	LV	Low	-	-
Vascular plant	*Solidago houghtonii* (Houghton's goldenrod)	-	●	-	-	-	SC	THR	G3	S2?	MV	VH	-	-
Vascular plant	*Solidago multiradiata* (Multi-rayed goldenrod)	●	-	-	-	-	-	-	G5	S4S5	HV	Low	-	-
Vascular plant	*Solidago ulmifolia* (Elm-leaved goldenrod)	-	-	●	-	-	-	-	G5	S1	MV	VH	-	-
Vascular plant	*Spiranthes magnicamporum* (Great Plains ladies'-tresses)	-	●	●	●	●	-	-	G4	S3?	LV	Low	-	-
Vascular plant	*Sporobolus heterolepis* (Prairie dropseed)	-	●	●	●	●	-	-	G5	S3	MV	VH	-	-
Vascular plant	*Sporobolus rigidus* var. *magnus* (Great Lakes sandreed)	-	●	●	●	-	-	-	G5T3T5	S3	MV	VH	-	-
Vascular plant	*Stylophorum diphyllum* (Wood poppy)	-	●	●	-	-	END	END	G5	S1	MV	Low	-	-
Vascular plant	*Tephrosia virginiana* (Virginia goat's-rue)	-	-	●	-	-	END	END	G5	S1	MV	VH	-	-
Vascular plant	*Tetraneuris herbacea* (Lakeside daisy)	-	●	-	-	-	THR	THR	G3	S3	HV	Mod	-	-
Vascular plant	*Triphora trianthophoros* (Nodding pogonia)	-	-	●	-	-	END	END	G3G4	S1	HV	Mod	-	-
Vascular plant	*Tsuga canadensis* (Eastern hemlock)	●	●	●	●	●	-	-	G5	S5	MV	VH	-	-

		Lake basin					Conservation status							
Taxonomic group	Species	Superior	Huron	Erie	Ontario	St Lawrence	COSEWIC[1]	COSSARO[1]	Grank[1]	Srank[1]	CCVI score[2]	Confidence[3]	Migratory	Migr exp[4]
Vascular plant	*Vaccinium ovalifolium* (Oval-leaved bilberry)	●	●	-	-	-	-	-	G5	S3	LV	Mod	-	-
Vascular plant	*Valeriana edulis* ssp. *ciliata* (Hairy valerian)	-	●	●	-	-	-	-	G5T3	S1	MV	VH	-	-
Vascular plant	*Valeriana uliginosa* (Swamp valerian)	-	●	●	●	●	-	-	G4Q	S2	MV	VH	-	-
Vascular plant	*Valerianella chenopodiifolia* (Goosefoot cornsalad)	-	-	-	●	-	-	-	G4	S1	MV	Mod	-	-
Vascular plant	*Viola striata* (Striped cream violet)	-	●	●	-	-	-	-	G5	S3	LV	Low	-	-
Vascular plant	*Woodsia alpina* (Alpine woodsia)	●	-	-	●	●	-	-	G4G5	S2	HV	Mod	-	-
Vascular plant	*Woodsia obtusa* (Blunt-lobed woodsia)	-	-	-	-	●	THR	END	G5	S1	LV	VH	-	-

[1]COSEWIC, COSSARO, Grank and Srank current as of 01 March, 2018. For conservation rank and at risk status definitions refer to Appendix A.
[2]Climate Change Vulnerability Index (CCVI) score abbreviations as follows: EV=extremely vulnerable, HV=highly vulnerable; MV =moderately vulnerable, LV=less vulnerable. See Glossary for more details.
[3]Climate Change Vulnerability Index (CCVI) calculated confidence levels as follows: VH=very high (>90% confidence); H=high (80–90% confidence), Mod=moderate (60 - 80% confidence); LOW=low (<60% confidence).
[4]Migratory bird exposure risk: H=high; M=moderate.

Appendix C: Climate Change Vulnerability Index exposure and sensitivity factor scoring

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Ambystoma maculatum (Spotted salamander)	0	0	4	95	1	0	0	62	38	0	0	0	-	-	-	-
Anaxyrus fowleri (Fowler's toad)	0	0	0	71	29	0	0	100	0	0	0	0	-	-	-	-
Desmognathus fuscus (Northern dusky salamander)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Desmognathus ochrophaeus (Allegheny mountain dusky salamander)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Hemidactylium scutatum (Four-toed salamander)	0	0	1	99	0	0	0	63	37	0	0	0	-	-	-	-
Lithobates palustris (Pickerel frog)	0	0	1	99	0	0	0	77	23	0	0	0	-	-	-	-
Lithobates septentrionalis (Mink frog)	0	0	15	85	0	0	0	44	56	0	0	0	-	-	-	-
Necturus maculosus (Mudpuppy)	0	0	1	89	10	0	3	65	32	0	0	0	-	-	-	-
Notophthalmus viridescens viridescens (Red-spotted newt)	0	0	5	94	1	0	0	62	38	0	0	0	-	-	-	-
Pseudacris crucifer (Spring peeper)	0	0	15	84	1	0	0	61	39	0	0	0	-	-	-	-
Pseudacris maculata (Boreal chorus frog)	0	0	82	18	0	0	0	92	8	0	0	0	-	-	-	-
Pseudacris triseriata pop. 1 (Western chorus frog, Great Lakes/St. Lawrence - Canadian Shield population)	0	0	0	100	0	0	0	66	34	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Pseudacris triseriata pop. 2 (Western chorus frog, Carolinian population)	0	0	0	80	20	0	13	87	0	0	0	0	-	-	-	-
Aix sponsa (Wood duck)	0	0	8	89	3	0	1	67	32	0	0	0	-	-	-	-
Anas discors (Blue-winged teal)	0	0	10	86	4	0	1	57	42	0	0	0	-	-	-	-
Anas rubripes (American black duck)	0	0	17	82	1	0	1	57	42	0	0	0	-	-	-	-
Antrostomus vociferus (Eastern whip-poor-will)	0	0	10	87	3	0	1	61	38	0	0	0	35	25	35	5
Asio flammeus (Short-eared owl)	0	0	29	67	4	0	3	69	28	0	0	0	-	-	-	-
Aythya collaris (Ring-necked duck)	0	0	33	67	0	0	0	41	59	0	0	0	-	-	-	-
Buteo lineatus (Red-shouldered hawk)	0	0	1	99	0	0	0	60	40	0	0	0	-	-	-	-
Butorides virescens (Green heron)	0	0	0	95	5	0	1	76	23	0	0	0	-	-	-	-
Cathartes aura (Turkey vulture)	0	0	11	86	3	0	1	69	30	0	0	0	-	-	-	-
Chaetura pelagica (Chimney swift)	0	0	1	95	4	0	1	52	47	0	0	0	60	20	15	5
Charadrius melodus (Piping plover)	0	0	0	92	8	0	0	75	25	0	0	0	30	-	70	-
Colinus virginianus (Northern bobwhite)	0	0	0	3	97	0	30	70	0	0	0	0	-	-	-	-
Contopus cooperi (Olive-sided flycatcher)	0	0	28	72	0	0	0	51	49	0	0	0	-	-	-	-
Coturnicops noveboracensis (Yellow rail)	0	0	23	77	0	0	0	51	49	0	0	0	-	-	-	-
Dolichonyx oryzivorus (Bobolink)	0	0	2	97	1	0	1	63	36	0	0	0	50	10	35	5
Empidonax virescens (Acadian flycatcher)	0	0	0	84	16	0	0	100	0	0	0	0	35	10	50	5
Euphagus carolinus (Rusty blackbird)	0	0	43	57	0	0	0	50	50	0	0	0	-	-	-	-
Falco peregrinus (Peregrine falcon)	0	0	45	54	1	0	1	71	28	0	0	0	20	10	40	30
Hirundo rustica (Barn swallow)	0	0	3	94	3	0	0	52	48	0	0	0	20	10	40	30

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Icteria virens (Yellow-breasted chat)	0	0	0	62	38	0	6	94	0	0	0	0	55	10	30	5
Ixobrychus exilis (Least bittern)	0	0	0	93	7	0	4	72	24	0	0	0	-	-	-	-
Lanius ludovicianus (Loggerhead shrike)	0	0	0	100	0	0	0	84	16	0	0	0	10	10	75	5
Melanerpes erythrocephalus (Red-headed woodpecker)	0	0	0	90	10	0	5	80	15	0	0	0	-	-	-	-
Meleagris gallopavo (Wild turkey)	0	0	0	97	3	0	1	74	25	0	0	0	-	-	-	-
Parkesia motacilla (Louisiana waterthrush)	0	0	0	96	4	0	2	90	8	0	0	0	40	20	35	5
Perisoreus canadensis (Gray jay)	0	0	57	43	0	0	0	61	39	0	0	0	-	-	-	-
Podilymbus podiceps (Pied-billed grebe)	0	0	11	86	3	0	1	63	36	0	0	0	-	-	-	-
Protonotaria citrea (Prothonotary warbler)	0	0	0	58	42	0	10	90	0	0	0	0	80	10	10	-
Rallus elegans (King rail)	0	0	0	61	39	0	17	67	16	0	0	0	-	-	-	-
Setophaga cerulea (Cerulean warbler)	0	0	0	97	3	0	1	77	22	0	0	0	30	20	45	5
Setophaga citrina (Hooded warbler)	0	0	0	94	6	0	2	97	1	0	0	0	-	-	-	-
Setophaga discolor (Prairie warbler)	0	0	0	100	0	0	0	48	52	0	0	0	-	-	-	-
Setophaga kirtlandii (Kirtland's warbler)	0	0	0	100	0	0	0	50	50	0	0	0	10	25	65	-
Sturnella magna (Eastern meadowlark)	0	0	1	97	2	0	1	66	33	0	0	0	-	-	-	-
Tyto alba (Barn owl)	0	0	0	50	50	0	0	100	0	0	0	0	-	-	-	-
Vermivora chrysoptera (Golden-winged warbler)	0	0	0	100	0	0	0	27	73	0	0	0	80	10	10	

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Amblyodon dealbatus (Short-toothed hump moss)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Aulacomnium acuminatum (Acutetip groove moss)	0	0	100	0	0	0	0	65	35	0	0	0	-	-	-	-
Bryoandersonia illecebra (Spoon-leaved moss)	0	0	0	82	18	0	11	89	0	0	0	0	-	-	-	-
Buxbaumia aphylla (Brown shield moss)	0	0	15	85	0	0	0	43	57	0	0	0	-	-	-	-
Fissidens exilis (Pygmy pocket moss)	0	0	0	40	60	0	40	60	0	0	0	0	-	-	-	-
Marsupella sphacelata (Speckled rustwort)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Meesia uliginosa (Capillary thread moss)	0	0	30	70	0	0	0	51	49	0	0	0	-	-	-	-
Mielichhoferia mielichhoferiana (Alpine copper moss)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Mnium thomsonii (Thomson's leafy moss)	0	0	37	63	0	0	0	62	38	0	0	0	-	-	-	-
Oncophorus virens (Green spur moss)	0	0	83	17	0	0	0	71	29	0	0	0	-	-	-	-
Porella pinnata (Pinnate scalewort)	0	0	0	100	0	0	0	25	75	0	0	0	-	-	-	-
Rhytidiadelphus subpinnatus (Square gooseneck moss)	0	0	40	60	0	0	0	70	30	0	0	0	-	-	-	-
Sphagnum cuspidatum (Feathery peat moss)	0	0	28	72	0	0	0	72	28	0	0	0	-	-	-	-
Sphagnum platyphyllum (Flat-leaved peat moss)	0	0	67	33	0	0	0	35	65	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Splachnum rubrum (Brilliant red dung moss)	0	0	91	9	0	0	0	82	18	0	0	0	-	-	-	-
Syntrichia cainii (Cain's screw moss)	0	0	0	100	0	0	0	37	63	0	0	0	-	-	-	-
Tetraplodon mnioides (Smooth-margin nitrogen moss)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Tetrodontium brownianum (Brown's four-toothed moss)	0	0	50	50	0	0	0	50	50	0	0	0	-	-	-	-
Tortula porteri (Porter's screw moss)	0	0	0	60	40	0	0	100	0	0	0	0	-	-	-	-
Acipenser fulvescens pop. 2 (Lake sturgeon, southern Hudson Bay/James Bay population)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Acipenser fulvescens pop. 3 (Lake sturgeon, Great Lakes-upper St. Lawrence River population)	0	0	25	68	7	0	1	58	41	0	0	0	-	-	-	-
Ammocrypta pellucida (Eastern sand darter)	0	0	0	72	28	0	22	78	0	0	0	0	-	-	-	-
Clinostomus elongatus (Redside dace)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Coregonus zenithicus (Shortjaw cisco)	0	0	89	11	0	0	0	76	24	0	0	0	-	-	-	-
Erimyzon sucetta (Lake chubsucker)	0	0	0	60	40	0	4	96	0	0	0	0	-	-	-	-
Esox americanus vermiculatus (Grass pickerel)	0	0	0	81	19	0	5	77	18	0	0	0	-	-	-	-
Exoglossum maxillingua (Cutlip minnow)	0	0	0	100	0	0	0	12	88	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Fundulus notatus (Blackstripe topminnow)	0	0	0	78	22	0	1	99	0	0	0	0	-	-	-	-
Ichthyomyzon fossor (Northern brook lamprey)	0	0	13	85	2	0	0	69	31	0	0	0	-	-	-	-
Lepisosteus oculatus (Spotted gar)	0	0	0	55	45	0	0	97	3	0	0	0	-	-	-	-
Lepomis gulosus (Warmouth)	0	0	0	65	35	0	0	100	0	0	0	0	-	-	-	-
Minytrema melanops (Spotted sucker)	0	0	0	42	58	0	19	81	0	0	0	0	-	-	-	-
Moxostoma carinatum (River redhorse)	0	0	0	97	3	0	0	81	19	0	0	0	-	-	-	-
Moxostoma duquesnei (Black redhorse)	0	0	0	98	2	0	0	97	3	0	0	0	-	-	-	-
Notropis photogenis (Silver shiner)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Noturus stigmosus (Northern madtom)	0	0	0	73	27	0	9	91	0	0	0	0	-	-	-	-
Opsopoeodus emiliae (Pugnose minnow)	0	0	0	36	64	0	21	79	0	0	0	0	-	-	-	-
Percina copelandi (Channel darter)	0	0	0	58	42	0	11	70	19	0	0	0	-	-	-	-
Aeshna juncea (Sedge darner)	0	0	100	0	0	0	0	50	50	0	0	0	-	-	-	-
Amphiagrion saucium (Eastern red damsel)	0	0	0	100	0	0	0	77	23	0	0	0	-	-	-	-
Atrytonopsis hianna (Dusted skipper)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Bombus affinis (Rusty-patched bumble bee)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Callophrys lanoraieensis (Bog elfin)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Erora laeta (Early hairstreak)	0	0	0	100	0	0	0	13	87	0	0	0	-	-	-	-
Erynnis martialis (Mottled duskywing)	0	0	0	95	5	0	0	76	24	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Gomphaeschna furcillata (Harlequin darner)	0	0	0	100	0	0	0	58	42	0	0	0	-	-	-	-
Lestes eurinus (Amber-winged spreadwing)	0	0	0	95	5	0	0	74	26	0	0	0	-	-	-	-
Nannothemis bella (Elfin skimmer)	0	0	0	100	0	0	0	73	27	0	0	0	-	-	-	-
Oarisma garita (Garita skipperling)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Pieris virginiensis (West Virginia white)	0	0	0	100	0	0	0	67	33	0	0	0	-	-	-	-
Rhionaeschna mutata (Spatterdock darner)	0	0	0	57	43	0	10	90	0	0	0	0	-	-	-	-
Sphodros niger (Black purse web spider)	0	0	0	74	26	0	13	87	0	0	0	0	-	-	-	-
Trimerotropis huroniana (Lake Huron grasshopper)	0	0	0	100	0	0	0	30	70	0	0	0	-	-	-	-
Williamsonia fletcheri (Ebony boghaunter)	0	0	4	96	0	0	0	32	68	0	0	0	-	-	-	-
Ahtiana aurescens (Eastern candlewax lichen)	0	0	67	33	0	0	0	100	0	0	0	0	-	-	-	-
Anaptychia crinalis (Hanging fringed lichen)	0	0	55	45	0	0	0	62	38	0	0	0	-	-	-	-
Arthrorhaphis alpina (Alpine dot lichen)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Bryoria pikei (Pike's horsehair lichen)	0	0	95	5	0	0	0	40	60	0	0	0	-	-	-	-
Cetraria laevigata (Pin-striped Icelandmoss lichen)	0	0	100	0	0	0	0	45	55	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Flavocetraria nivalis (Crinkled snow lichen)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Heppia adglutinata (Soil ruby lichen)	0	0	0	100	0	0	0	60	40	0	0	0	-	-	-	-
Leptogium corticola (Blistered jellyskin lichen)	0	0	33	67	0	0	0	33	67	0	0	0	-	-	-	-
Leptogium rivulare (Flooded jellyskin)	0	0	1	99	0	0	0	53	47	0	0	0	-	-	-	-
Lobaria pulmonaria (Lungwort lichen)	0	0	64	36	0	0	0	63	37	0	0	0	-	-	-	-
Parmotrema hypotropum (Southern powdered ruffle lichen)	0	0	0	75	25	0	20	80	0	0	0	0	-	-	-	-
Physconia subpallida (Pale-bellied frost lichen)	0	0	0	100	0	0	0	52	48	0	0	0	-	-	-	-
Pseudocyphellaria holarctica (Yellow specklebelly lichen)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Punctelia appalachensis (Appalachian speckled shield lichen)	0	0	25	75	0	0	0	50	50	0	0	0	-	-	-	-
Sticta beauvoisii (Fingered moon lichen)	0	0	50	50	0	0	0	50	50	0	0	0	-	-	-	-
Teloschistes chrysophthalmus pop. 1 (Golden-eye lichen, Great Lakes population)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Thyrea confusa (Jelly-strap lichen)	0	0	0	100	0	0	0	58	42	0	0	0	-	-	-	-
Usnea longissima (Methuselah's beard lichen)	0	0	100	0	0	0	0	32	68	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Xanthoria parietina (Maritime sunburst lichen)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Alces americanus (Moose)	0	0	69	31	0	0	0	64	36	0	0	0	-	-	-	-
Didelphis virginiana (Virginia opossum)	0	0	10	90	0	0	5	91	4	0	0	0	-	-	-	-
Lepus americanus (Snowshoe hare)	0	0	37	63	0	0	0	47	53	0	0	0	-	-	-	-
Lynx canadensis (Canada lynx)	0	0	57	43	0	0	0	58	42	0	0	0	-	-	-	-
Microtus pinetorum (Woodland vole)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Myotis septentrionalis (Northern myotis)	0	0	21	79	0	0	0	60	40	0	0	0	-	-	-	-
Perimyotis subflavusi (Tricolored bat)	0	0	3	94	3	0	0	74	26	0	0	0	-	-	-	-
Rangifer tarandus (Caribou, boreal pop.)	0	0	100	0	0	0	0	89	11	0	0	0	-	-	-	-
Scalopus aquaticus (Eastern mole)	0	0	0	0	100	0	15	85	0	0	0	0	-	-	-	-
Taxidea taxus (American badger)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Urocyon cinereoargenteus (Gray fox)	0	0	33	33	34	0	0	100	0	0	0	0	-	-	-	-
Anguispira kochi (Banded globe)	0	0	0	0	100	0	50	50	0	0	0	0	-	-	-	-
Epioblasma torulosa rangiana (Northern riffleshell)	0	0	0	77	23	0	25	75	0	0	0	0	-	-	-	-
Epioblasma triquetra (Snuffbox)	0	0	0	89	11	0	0	100	0	0	0	0	-	-	-	-
Ligumia nasuta (Eastern pondmussel)	0	0	0	66	34	0	33	34	33	0	0	0	-	-	-	-
Mesodon clausus (Yellow gobelet)	0	0	0	0	100	0	0	100	0	0	0	0	-	-	-	-
Simpsonaias ambigua (Salamander mussel)	0	0	0	80	20	0	20	80	0	0	0	0	-	-	-	-
Villosa fabalis (Rayed bean)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-

	Temperature scope						Climate moisture deficit scope						Migratory exposure			
Species	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Chelydra serpentina (Snapping turtle)	0	0	3	94	3	0	1	68	31	0	0	0	-	-	-	-
Clemmys guttata (Spotted turtle)	0	0	0	90	10	0	1	60	39	0	0	0	-	-	-	-
Coluber constrictor foxii (Blue racer)	0	0	0	0	100	0	0	100	0	0	0	0	-	-	-	-
Emydoidea blandingii (Blanding's turtle)	0	0	2	94	4	0	2	57	41	0	0	0	-	-	-	-
Glyptemys insculpta (Wood turtle)	0	0	7	93	0	0	0	85	15	0	0	0	-	-	-	-
Graptemys geographica (Northern map turtle)	0	0	1	89	10	0	2	68	30	0	0	0	-	-	-	-
Nerodia sipedon insularum (Lake Erie watersnake)	0	0	0	0	100	0	5	95	0	0	0	0	-	-	-	-
Opheodrys vernalis (Smooth greensnake)	0	0	5	94	1	0	1	55	44	0	0	0	-	-	-	-
Pantherophis gloydi pop. 1 (Eastern foxsnake, Georgian Bay population)	0	0	0	100	0	0	0	37	63	0	0	0	-	-	-	-
Pantherophis gloydi pop. 2 (Eastern foxsnake, Carolinian population)	0	0	0	35	65	0	20	80	0	0	0	0	-	-	-	-
Pantherophis spiloides pop. 1 (Eastern ratsnake, Great Lakes - St. Lawrence population)	0	0	0	100	0	0	0	35	65	0	0	0	-	-	-	-
Pantherophis spiloides pop. 2 (Eastern ratsnake, Carolinian population)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Plestiodon fasciatus pop. 1 (Common five-lined skink, Carolinian population)	0	0	0	53	47	0	6	94	0	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Plestiodon fasciatus pop. 2 (Common five-lined skink, southern Shield population)	0	0	0	100	0	0	0	58	42	0	0	0	-	-	-	-
Regina septemvittata (Queensnake)	0	0	0	78	22	0	10	77	13	0	0	0	-	-	-	-
Thamnophis butleri (Butler's gartersnake)	0	0	0	48	52	0	30	70	0	0	0	0	-	-	-	-
Acer saccharum (Sugar maple)	0	0	21	54	25	0	1	53	46	0	0	0	-	-	-	-
Adenocaulon bicolor (Pathfinder)	0	0	0	100	0	0	0	40	60	0	0	0	-	-	-	-
Adoxa moschatellina (Muskroot)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Aplectrum hyemale (Puttyroot)	0	0	0	86	14	0	3	80	17	0	0	0	-	-	-	-
Asplenium ruta-muraria (Wallrue spleenwort)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Asplenium scolopendrium var. *americanum* (American Hart's-tongue fern)	0	0	0	100	0	0	0	67	33	0	0	0	-	-	-	-
Astragalus neglectus (Neglected milk-vetch)	0	0	0	100	0	0	0	55	45	0	0	0	-	-	-	-
Aureolaria pedicularia (Fern-leaved false foxglove)	0	0	0	78	22	0	11	89	0	0	0	0	-	-	-	-
Azolla cristata (Eastern mosquito fern)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Bartonia paniculata spp. *paniculata* (Branched bartonia)	0	0	0	100	0	0	0	65	35	0	0	0	-	-	-	-
Botrychium ascendens (Upswept moonwort)	0	0	100	0	0	0	0	0	100	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Botrychium pallidum (Pale moonwort)	0	0	100	0	0	0	0	85	15	0	0	0	-	-	-	-
Botrychium spathulatum (Spatulate moonwort)	0	0	90	10	0	0	0	40	60	0	0	0	-	-	-	-
Bouteloua curtipendula (Side-oats grama)	0	0	0	100	0	0	0	93	7	0	0	0	-	-	-	-
Carex aggregata (Glomerate sedge)	0	0	0	0	100	0	0	100	0	0	0	0	-	-	-	-
Carex alata (Broad-winged sedge)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Carex atratiformis (Black sedge)	0	0	85	15	0	0	0	93	7	0	0	0	-	-	-	-
Carex juniperorum (Juniper sedge)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Carex loliacea (Ryegrass sedge)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Carex lupuliformis (False hop sedge)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Carex nigromarginata (Black-edged sedge)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Carex schweinitzii (Schweinitz's sedge)	0	0	0	100	0	0	0	88	12	0	0	0	-	-	-	-
Carex wiegandii (Wiegand's sedge)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Carya laciniosa (Shellbark hickory)	0	0	0	50	50	0	20	80	0	0	0	0	-	-	-	-
Castanea dentata (American chestnut)	0	0	0	85	15	0	10	90	0	0	0	0	-	-	-	-
Celtis tenuifolia (Dwarf hackberry)	0	0	0	75	25	0	17	83	0	0	0	0	-	-	-	-
Chamaenerion latifolium (River beauty)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Chimaphila maculata (Spotted wintergreen)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Cirsium pitcheri (Pitcher's thistle)	0	0	13	87	0	0	0	31	69	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Conioselinum chinense (Chinese hemlock-parsley)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Coptidium lapponicum (Lapland buttercup)	0	0	27	73	0	0	0	91	9	0	0	0	-	-	-	-
Cornus florida (Flowering dogwood)	0	0	0	85	15	0	5	95	0	0	0	0	-	-	-	-
Cuscuta cephalanthi (Buttonbush dodder)	0	0	0	60	40	0	40	30	30	0	0	0	-	-	-	-
Cypripedium arietinum (Ram's-head lady's-slipper)	0	0	3	97	0	0	0	30	70	0	0	0	-	-	-	-
Cypripedium candidum (Small white lady's-slipper)	0	0	0	25	75	0	25	75	0	0	0	0	-	-	-	-
Cypripedium passerinum (Sparrow's-egg lady's-slipper)	0	0	100	0	0	0	0	0	100	0	0	0	-	-	-	-
Cystopteris laurentiana (Laurentian bladder fern)	0	0	42	58	0	0	0	21	79	0	0	0	-	-	-	-
Cystopteris montana (Mountain bladder fern)	0	0	100	0	0	0	0	0	100	0	0	0	-	-	-	-
Draba aurea (Golden draba)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Dryas drummondii (Yellow Mountain-avens)	0	0	100	0	0	0	0	0	100	0	0	0	-	-	-	-
Eleocharis equisetoides (Horsetail spikerush)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Eleocharis geniculata (Bent spikerush)	0	0	0	50	50	0	0	100	0	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Elymus lanceolatus ssp. *psammophilus* (Great Lakes wild rye)	0	0	0	100	0	0	0	24	76	0	0	0	-	-	-	-
Enemion biternatum (False rue-anemone)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Erigeron hyssopifolius (Daisy fleabane)	0	0	87	13	0	0	0	55	45	0	0	0	-	-	-	-
Euphorbia commutata (Tinted woodland spurge)	0	0	0	100	0	0	0	50	50	0	0	0	-	-	-	-
Fraxinus nigra (Black ash)	0	0	44	55	1	0	1	62	37	0	0	0	-	-	-	-
Fraxinus profunda (Pumpkin ash)	0	0	0	52	48	0	18	82	0	0	0	0	-	-	-	-
Gentiana alba (White prairie gentian)	0	0	0	0	100	0	100	0	0	0	0	0	-	-	-	-
Gratiola quartermaniae (Limestone hedge-hyssop)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Gymnocarpium continentale (Nahanni oak fern)	0	0	100	0	0	0	0	87	13	0	0	0	-	-	-	-
Hibiscus moscheutos (Swamp rose mallow)	0	0	0	39	61	0	38	62	0	0	0	0	-	-	-	-
Hudsonia tomentosa (Woolly beach-heath)	0	0	44	56	0	0	0	70	30	0	0	0	-	-	-	-
Hydrastis canadensis (Goldenseal)	0	0	0	60	40	0	15	85	0	0	0	0	-	-	-	-
Hypericum prolificum (Shubby St. John's-wort)	0	0	0	40	60	0	40	60	0	0	0	0	-	-	-	-
Iris brevicaulis (Short-stemmed iris)	0	0	0	0	100	0	50	50	0	0	0	0	-	-	-	-
Iris lacustris (Dwarf lake iris)	0	0	0	100	0	0	0	3	97	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Isoetes engelmannii (Engelmann's quillwort)	0	0	0	100	0	0	0	50	50	0	0	0	-	-	-	-
Isoetes tuckermanii (Tuckerman's quillwort)	0	0	0	100	0	0	0	40	60	0	0	0	-	-	-	-
Isotria medeoloides (Small whorled Pogonia)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Juglans cinerea (Butternut)	0	0	0	86	14	0	0	60	40	0	0	0	-	-	-	-
Justicia americana (American water-willow)	0	0	0	64	36	0	18	73	9	0	0	0	-	-	-	-
Lespedeza virginica (Slender bush-clover)	0	0	0	0	100	0	100	0	0	0	0	0	-	-	-	-
Linum striatum (Ridged yellow flax)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Liparis liliifolia (Purple twayblade)	0	0	0	33	67	0	53	41	6	0	0	0	-	-	-	-
Lupinus perennis (Sundial lupine)	0	0	0	83	17	0	11	89	0	0	0	0	-	-	-	-
Magnolia acuminata (Cucumber magnolia)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Malaxis paludosa (Bog adder's-mouth)	0	0	100	0	0	0	0	72	28	0	0	0	-	-	-	-
Moehringia macrophylla (Large-leaved sandwort)	0	0	80	20	0	0	0	82	18	0	0	0	-	-	-	-
Muhlenbergia richardsonis (Mat muhly)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Nelumbo lutea (American lotus)	0	0	0	80	20	0	50	50	0	0	0	0	-	-	-	-
Nyssa sylvatica (Black gum)	0	0	0	72	28	0	1	99	0	0	0	0	-	-	-	-
Oplopanax horridus (Devil's club)	0	0	100	0	0	0	0	67	33	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Opuntia fragilis (Brittle prickly-pear)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Orobanche fasciculata (Clustered broomrape)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Oxytropis splendens (Showy locoweed)	0	0	100	0	0	0	0	67	33	0	0	0	-	-	-	-
Peltandra virginica (Green arrow arum)	0	0	0	100	0	0	0	63	37	0	0	0	-	-	-	-
Phacelia franklinii (Franklin's phacelia)	0	0	81	19	0	0	0	95	5	0	0	0	-	-	-	-
Phacelia purshii (Miami-mist)	0	0	0	0	100	0	40	60	0	0	0	0	-	-	-	-
Picea glauca (White spruce)	0	0	53	47	0	0	0	60	40	0	0	0	-	-	-	-
Picea rubens (Red spruce)	0	0	0	100	0	0	0	10	90	0	0	0	-	-	-	-
Pinus rigida (Pitch pine)	0	0	0	100	0	0	0	55	45	0	0	0	-	-	-	-
Pinus strobus (Eastern white pine)	0	0	35	63	2	0	0	67	33	0	0	0	-	-	-	-
Plantago cordata (Heart-leaved plantain)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Platanthera grandiflora (Large purple fringed orchid)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Platanthera leucophaea (Eastern prairie fringed orchid)	0	0	0	56	44	0	20	40	40	0	0	0	-	-	-	-
Podostemum ceratophyllum (Horn-leaved riverweed)	0	0	0	100	0	0	0	72	28	0	0	0	-	-	-	-
Polygala incarnata (Pink milkwort)	0	0	0	0	100	0	100	0	0	0	0	0	-	-	-	-
Polystichum braunii (Braun's holly fern)	0	0	30	70	0	0	0	90	10	0	0	0	-	-	-	-
Populus heterophylla (Swamp cottonwood)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-

	Temperature scope						Climate moisture deficit scope						Migratory exposure			
Species	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Potamogeton hillii (Hill's pondweed)	0	0	0	100	0	0	0	21	79	0	0	0	-	-	-	-
Ptelea trifoliata (Common hoptree)	0	0	0	38	62	0	19	81	0	0	0	0	-	-	-	-
Pterospora andromedea (Woodland pinedrops)	0	0	10	90	0	0	0	55	45	0	0	0	-	-	-	-
Pyrola grandiflora (Arctic pyrola)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Quercus ellipsoidalis (Northern pin oak)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Quercus ilicifolia (Bear Oak)	0	0	0	100	0	0	0	40	60	0	0	0	-	-	-	-
Quercus muehlenbergii (Chinquapin oak)	0	0	0	85	15	0	5	91	4	0	0	0	-	-	-	-
Rhododendron canadense (Rhodora)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Rotala ramosior (Lowland toothcup)	0	0	0	100	0	0	0	30	70	0	0	0	-	-	-	-
Sassafras albidum (Sassafras)	0	0	0	80	20	0	10	90	0	0	0	0	-	-	-	-
Saxifraga oppositifolia (Purple mountain saxifrage)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Saxifraga paniculata (Encrusted saxifrage)	0	0	89	11	0	0	0	65	35	0	0	0	-	-	-	-
Scleria verticillata (Low nutrush)	0	0	0	95	5	0	0	55	45	0	0	0	-	-	-	-
Sida hermaphrodita (Virginia mallow)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Silene acaulis (Moss campion)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Smilax rotundifolia (Round-leaved greenbrier)	0	0	0	56	44	0	3	97	0	0	0	0	-	-	-	-
Solidago houghtonii (Houghton's goldenrod)	0	0	0	100	0	0	0	13	87	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Solidago multiradiata (Multi-rayed goldenrod)	0	0	100	0	0	0	0	100	0	0	0	0	-	-	-	-
Solidago ulmifolia (Elm-leaved goldenrod)	0	0	0	0	100	0	0	100	0	0	0	0	-	-	-	-
Spiranthes magnicamporum (Great Plains ladies'-tresses)	0	0	0	63	37	0	5	90	5	0	0	0	-	-	-	-
Sporobolus heterolepis (Prairie dropseed)	0	0	0	100	0	0	0	30	70	0	0	0	-	-	-	-
Sporobolus rigidus var. *magnus* (Great Lakes sandreed)	0	0	0	100	0	0	0	39	61	0	0	0	-	-	-	-
Stylophorum diphyllum (Wood poppy)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Tephrosia virginiana (Virginia goat's-rue)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Tetraneuris herbacea (Lakeside daisy)	0	0	0	100	0	0	0	17	83	0	0	0	-	-	-	-
Triphora trianthophoros (Nodding pogonia)	0	0	0	0	100	0	0	100	0	0	0	0	-	-	-	-
Tsuga canadensis (Eastern hemlock)	0	0	3	97	0	0	0	49	51	0	0	0	-	-	-	-
Vaccinium ovalifolium (Oval-leaved bilberry)	0	0	50	50	0	0	0	88	12	0	0	0	-	-	-	-
Valeriana edulis ssp. *ciliata* (Hairy valerian)	0	0	0	100	0	0	0	100	0	0	0	0	-	-	-	-
Valeriana uliginosa (Swamp valerian)	0	0	0	100	0	0	0	87	13	0	0	0	-	-	-	-
Valerianella chenopodiifolia (Goosefoot cornsalad)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-
Viola striata (Striped cream violet)	0	0	0	84	16	0	10	90	0	0	0	0	-	-	-	-

Species	Temperature scope						Climate moisture deficit scope						Migratory exposure			
	>3.8C	3.49 - 3.8C	3.17 - 3.48C	2.85 - 3.16C	2.53 - 2.84C	<2.53C	>56.68	38.87 - 56.68	21.05 - 38.86	3.23 - 21.04	-14.59 - 3.22	< -14.59	>7	6-7	4-5	2-3
Woodsia alpina (Alpine woodsia)	0	0	92	8	0	0	0	79	21	0	0	0	-	-	-	-
Woodsia obtusa (Blunt-lobed woodsia)	0	0	0	100	0	0	0	0	100	0	0	0	-	-	-	-

Appendix D. Climate Change Vulnerability Index intrinsic and modelled risk factor scores

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Ambystoma maculatum (Spotted salamander)	N	N	SI	N	SI-N	SI	N	N	Inc	N	N	SI-N
Anaxyrus fowleri (Fowler's toad)	N	Inc	Inc-SI	N	N	Inc	N	N	Inc	N	N	SI-N
Desmognathus fuscus (Northern dusky salamander)	N	GI-Inc	GI	N	SI	Inc	SI-N	N	N	N	N	SI-N
Desmognathus ochrophaeus (Allegheny mountain dusky salamander)	N	GI-Inc	GI	N	SI	Inc	SI-N	N	N	N	N	SI-N
Hemidactylium scutatum (Four-toed salamander)	N	N	SI	N	SI	Inc-SI	SI-N	N	SI	N	N	SI-N
Lithobates palustris (Pickerel frog)	N	N	SI-N	N	N	SI	SI-N	N	Inc	N	N	SI-N
Lithobates septentrionalis (Mink frog)	N	N	N	N	N	SI-N	SI	N	Inc-SI	N	N	N
Necturus maculosus (Mudpuppy)	N	N	SI	N	N	Inc-SI	N	N	N	N	N	N
Notophthalmus viridescens viridescens (Red-spotted newt)	N	N	SI	N	SI	SI	N	N	SI	N	N	N
Pseudacris crucifer (Spring peeper)	N	N	SI	N	SI	Inc-SI-N	N	N	Inc-SI	N	N	N
Pseudacris maculata (Boreal chorus frog)	N	Inc	N	N	SI-N	N	SI	N	SI-N	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Pseudacris triseriata pop. 1 (Western chorus frog, Great Lakes/St. Lawrence - Canadian Shield population)	N	N	Inc-SI-N	N	Inc-SI-N	SI	N	N	Inc-SI	N	N	N
Pseudacris triseriata pop. 2 (Western chorus frog, Carolinian population)	N	N	Inc	N	Inc-SI-N	Inc-SI	N	N	Inc	N	N	N
Aix sponsa (Wood duck)	N	N	N	N	N	SI	N	N	Inc-SI	N	N	N
Anas discors (Blue-winged teal)	N	N	N	N	N	SI	N	N	GI	N	N	N
Anas rubripes (American black duck)	N	N	N	N	N	SI	N	N	Inc-SI	N	N	N
Antrostomus vociferus (Eastern whip-poor-will)	N	N	N	N	N	Inc-SI-N	N	N	Inc-SI	N	N	N
Asio flammeus (Short-eared owl)	N	N	N	N	N	Inc-SI-N	N	N	SI-N	N	N	N
Aythya collaris (Ring-necked duck)	N	N	N	N	N	SI-N	N	N	Inc-SI	N	N	N
Buteo lineatus (Red-shouldered hawk)	N	N	N	N	N	SI	N	N	Inc	N	N	N
Butorides virescens (Green heron)	N	N	N	N	N	Inc-SI-N	N	N	N	N	N	N
Cathartes aura (Turkey vulture)	N	N	N	N	N	SI	N	N	N	U	N	N
Chaetura pelagica (Chimney swift)	N	N	N	N	N	SI	N	N	Inc	U	N	Inc-SI
Charadrius melodus (Piping plover)	N	N	N	N	N	Inc-SI	N	N	Inc	Inc-SI	N	Inc-SI
Colinus virginianus (Northern bobwhite)	N	N	SI	N	N	SI	N	N	N	SI	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Contopus cooperi (Olive-sided flycatcher)	N	N	N	SI	N	SI-N	N	N	N	N	N	N
Coturnicops noveboracensis (Yellow rail)	N	N	N	Inc	N	SI-N	N	N	GI	N	N	N
Dolichonyx oryzivorus (Bobolink)	N	N	N	N	N	SI	N	N	SI	N	N	N
Empidonax virescens (Acadian flycatcher)	N	N	N	N	N	Inc-SI	N	N	SI	N	N	N
Euphagus carolinus (Rusty blackbird)	N	N	N	N	N	SI-N	N	N	Inc-SI	N	N	N
Falco peregrinus (Peregrine falcon)	N	N	N	N	N	SI-N	N	N	N	SI-N	N	N
Hirundo rustica (Barn swallow)	N	N	N	N	N	SI	SI-N	N	SI	N	N	N
Icteria virens (Yellow-breasted chat)	N	N	N	N	N	Inc-SI	N	N	N	N	N	N
Ixobrychus exilis (Least bittern)	N	N	N	N	N	SI	N	N	Inc-SI	N	N	N
Lanius ludovicianus (Loggerhead shrike)	N	N	N	N	N	SI	N	N	N	SI-N	N	SI-N
Melanerpes erythrocephalus (Red-headed woodpecker)	N	N	N	N	N	SI	N	N	N	N	N	N
Meleagris gallopavo (Wild turkey)	N	N	N	N	N	SI	N	N	N	N	N	N
Parkesia motacilla (Louisiana waterthrush)	N	N	N	N	N	Inc-SI	SI-N	N	Inc	Inc-SI	N	SI
Perisoreus canadensis (Gray jay)	N	N	N	N	N	SI-N	SI	N	N	N	Inc	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Podilymbus podiceps (Pied-billed grebe)	N	N	N	N	N	SI	N	N	Inc-SI	N	N	N
Protonotaria citrea (Prothonotary warbler)	N	N	N	N	N	Inc-SI	N	N	GI	SI-N	N	N
Rallus elegans (King rail)	N	N	N	N	N	Inc-SI	SI	N	Inc	SI	N	N
Setophaga cerulea (Cerulean warbler)	N	N	N	N	N	SI	N	N	SI-N	N	N	N
Setophaga citrina (Hooded warbler)	N	N	N	N	N	Inc-SI	N	N	N	N	N	N
Setophaga discolor (Prairie warbler)	N	N	N	N	N	SI	N	N	N	N	N	SI
Setophaga kirtlandii (Kirtland's warbler)	N	N	N	N	N	SI-N	N	N	SI-N	N	N	N
Sturnella magna (Eastern meadowlark)	N	N	N	N	N	SI	SI	N	SI	N	N	N
Tyto alba (Barn owl)	N	N	N	N	N	Inc-SI	N	N	SI-N	N	N	N
Vermivora chrysoptera (Golden-winged warbler)	N	N	N	N	N	SI	N	N	SI	N	N	N
Amblyodon dealbatus (Short-toothed hump moss)	N	N	SI-N	N	Inc-SI-N	Inc	SI-N	N	Inc	N	N	SI
Aulacomnium acuminatum (Acutetip groove moss)	N	N	N	N	U	SI-N	GI	N	N	N	SI	SI-N
Bryoandersonia illecebra (Spoon-leaved moss)	N	N	GI	U	Inc	Inc-SI	N	N	SI	N	N	N
Buxbaumia aphylla (Brown shield moss)	N	N	N	N	Inc-SI-N	SI	N	N	N	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Fissidens exilis (Pygmy pocket moss)	N	N	Inc	N	N	Inc-Sl	N	N	N	Sl	N	N
Marsupella sphacelata (Speckled rustwort)	N	N	N	N	Inc-Sl-N	Sl	Sl	N	Inc	N	Sl-N	N
Meesia uliginosa (Capillary thread moss)	N	N	N	N	Inc-Sl-N	Inc-Sl	U	N	Gl-Inc	N	N	Sl
Mielichhoferia mielichhoferiana (Alpine copper moss)	N	Inc	N	N	Inc-Sl-N	Sl-N	U	N	Inc-Sl	N	N	Inc
Mnium thomsonii (Thomson's leafy moss)	N	N	N	N	Inc-Sl-N	Inc-Sl-N	N	N	Sl	N	N	N
Oncophorus virens (Green spur moss)	N	N	N	N	Inc-Sl-N	Sl-N	Sl	N	Sl	N	N	Sl-N
Porella pinnata (Pinnate scalewort)	N	N	N	N	Inc-Sl-N	Sl	N	N	Gl-Inc	N	N	N
Rhytidiadelphus subpinnatus (Square gooseneck moss)	N	N	N	N	Inc-Sl-N	Sl	Sl-N	N	Inc	N	N	N
Sphagnum cuspidatum (Feathery peat moss)	N	N	N	N	Sl-N	Sl	Sl	N	Inc	N	N	N
Sphagnum platyphyllum (Flat-leaved peat moss)	N	N	N	N	Sl-N	Sl	Sl-N	N	Sl	N	N	N
Splachnum rubrum (Brilliant red dung moss)	N	N	N	N	N	N	Inc	N	Inc	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Syntrichia cainii (Cain's screw moss)	N	Inc-SI	N	N	Inc-SI	Inc-SI	N	N	SI-N	N	N	Inc
Tetraplodon mnioides (Smooth-margin nitrogen moss)	N	N	N	N	Inc-SI-N	SI-N	SI-N	N	SI	N	N	N
Tetrodontium brownianum (Brown's four-toothed moss)	N	N	N	N	Inc-SI-N	SI	SI-N	N	N	N	N	SI
Tortula porteri (Porter's screw moss)	N	SI	Inc	N	U	SI	SI	N	SI	N	N	Inc
Acipenser fulvescens pop. 2 (Lake sturgeon, southern Hudson Bay - James Bay population)	N	SI-N	SI	Inc-SI	N	N	Inc-SI	N	GI-Inc	U	N	N
Acipenser fulvescens pop. 3 (Lake sturgeon, Great Lakes-upper St. Lawrence River population)	N	SI-N	GI-Inc	SI	N	Inc-SI-N	Inc-SI	N	GI-Inc	U	N	N
Ammocrypta pellucida (Eastern sand darter)	N	SI	Inc	N	Inc-SI	Inc-SI	SI-N	N	SI	SI	N	SI
Clinostomus elongatus (Redside dace)	N	SI	Inc-SI	N	Inc	SI	GI-Inc	N	GI	SI	N	SI
Coregonus zenithicus (Shortjaw cisco)	N	Inc	N	N	SI-N	SI-N	GI	N	N	SI	Inc	N
Erimyzon sucetta (Lake chubsucker)	N	SI	GI-Inc	N	N	Inc-SI	N	N	SI	SI	N	N
Esox americanus vermiculatus (Grass pickerel)	N	SI	SI	N	N	SI	N	N	Inc	SI	N	SI

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Exoglossum maxillingua (Cutlip minnow)	N	SI	SI-N	N	SI-N	N	N	SI	SI	SI-N	N	N
Fundulus notatus (Blackstripe topminnow)	N	SI	SI-N	N	N	SI	N	N	SI	N	N	N
Ichthyomyzon fossor (Northern brook lamprey)	N	SI	Inc	N	SI	Inc-SI-N	SI	N	Inc-SI	SI	SI	N
Lepisosteus oculatus (Spotted gar)	N	SI	SI	N	N	Inc-SI	N	N	GI-Inc	SI-N	N	SI
Lepomis gulosus (Warmouth)	N	SI	N	N	SI-N	SI	N	N	N	SI	N	N
Minytrema melanops (Spotted sucker)	N	SI	SI-N	N	SI-N	SI	N	N	SI	N	N	N
Moxostoma carinatum (River redhorse)	N	SI	Inc	N	N	SI	SI	N	SI	SI	N	N
Moxostoma duquesnei (Black redhorse)	N	GI	SI	N	N	Inc-SI	Inc-SI	N	Inc-SI	SI	N	N
Notropis photogenis (Silver shiner)	N	GI	Inc-SI	N	SI-N	SI	N	N	SI-N	SI-N	N	N
Noturus stigmosus (Northern madtom)	N	GI	SI	N	N	SI	N	N	Inc-SI	N	N	N
Opsopoeodus emiliae (Pugnose minnow)	N	SI	Inc-SI	N	SI	SI	N	N	Inc	SI	N	N
Percina copelandi (Channel darter)	N	SI	Inc-SI	N	SI	SI	N	N	Inc	SI	N	SI-N
Aeshna juncea (Sedge darner)	N	N	N	N	N	SI-N	GI	N	Inc-SI	N	N	N
Amphiagrion saucium (Eastern red damsel)	N	N	N	N	N	Inc-SI	N	N	Inc-SI	N	N	SI

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Atrytonopsis hianna (Dusted skipper)	N	N	GI	N	N	Inc-SI	N	N	N	N	N	Inc
Bombus affinis (Rusty-patched bumble bee)	N	N	Inc-SI	N	N	Inc-SI	N	N	N	N	N	N
Callophrys lanoraieensis (Bog elfin)	N	GI	U	N	N	SI	N	N	GI	N	N	SI
Erora laeta (Early hairstreak)	N	N	N	N	N	SI	N	N	N	N	N	N
Erynnis martialis (Mottled duskywing)	N	N	GI	N	N	SI	N	N	N	N	N	SI
Gomphaeschna furcillata (Harlequin darner)	N	N	N	N	N	SI	Inc	N	Inc-SI	N	N	N
Lestes eurinus (Amber-winged spreadwing)	N	N	N	N	N	SI	N	N	Inc	N	N	N
Nannothemis bella (Elfin skimmer)	N	N	N	N	N	Inc-SI	N	N	GI-Inc	N	N	N
Oarisma garita (Garita skipperling)	N	GI	N	N	N	SI	N	N	N	N	N	Inc
Pieris virginiensis (West Virginia white)	N	N	SI	N	N	SI	N	N	Inc	N	N	SI
Rhionaeschna mutata (Spatterdock darner)	N	N	N	N	N	SI	N	N	Inc-SI	N	N	N
Sphodros niger (Black purse web spider)	N	N	SI-N	N	N	SI	N	N	Inc-N	N	N	N
Trimerotropis huroniana (Lake Huron grasshopper)	N	GI	N	N	SI	SI	N	N	N	N	N	Inc

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Williamsonia fletcheri (Ebony boghaunter)	N	N	N	N	N	N	Inc-SI	N	Inc-SI	N	N	N
Ahtiana aurescens (Eastern candlewax lichen)	N	N	N	N	SI	SI-N	Inc-SI	N	SI	N	N	N
Anaptychia crinalis (Hanging fringed lichen)	N	N	SI	Inc	N	SI-N	SI	N	SI-N	N	N	SI-N
Arthrorhaphis alpina (Alpine dot lichen)	N	Inc	N	N	N	N	SI-N	N	N	N	GI-N	Inc
Bryoria pikei (Pike's horsehair lichen)	N	N	N	N	Inc	SI	SI	N	GI-Inc	U	N	N
Cetraria laevigata (Pin-striped Icelandmoss lichen)	N	SI	N	N	N	SI	GI-Inc	N	N	N	N	N
Flavocetraria nivalis (Crinkled snow lichen)	N	GI	N	N	SI-N	SI-N	GI-Inc	N	N	N	N	N
Heppia adglutinata (Soil ruby lichen)	N	N	SI-N	N	N	SI	N	N	N	N	N	Inc
Leptogium corticola (Blistered jellyskin lichen)	N	N	N	N	SI	SI-N	SI	N	SI-N	N	N	N
Leptogium rivulare (Flooded jellyskin)	N	N	SI	N	SI-N	SI	N	N	GI	SI	N	N
Lobaria pulmonaria (Lungwort lichen)	N	N	N	N	Inc	SI-N	SI-N	N	N	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Parmotrema hypotropum (Southern powdered ruffle lichen)	N	N	SI-N	SI-N	N	Inc-SI	N	N	N	N	N	N
Physconia subpallida (Pale-bellied frost lichen)	N	SI	SI-N	N	SI	SI	N	SI-N	N	N	N	N
Pseudocyphellaria holarctica (Yellow specklebelly lichen)	N	N	N	N	Inc-SI	N	Inc	N	GI-Inc	N	N	SI
Punctelia appalachensis (Appalachian speckled shield lichen)	N	SI-N	N	N	Inc-SI	Inc	N	N	N	N	N	N
Sticta beauvoisii (Fingered moon lichen)	N	N	N	N	Inc	SI-N	SI	N	GI-Inc	N	N	N
Teloschistes chrysophthalmus pop. 1 (Golden-eye lichen, Great Lakes population)	N	N	N	SI	N	SI	N	N	SI-N	N	N	SI-N
Thyrea confusa (Jelly-strap lichen)	N	N	N	N	SI	SI	N	N	SI-N	N	N	Inc
Usnea longissima (Methuselah's beard lichen)	N	N	N	SI	Inc	SI-N	SI	N	SI-N	SI	N	N
Xanthoria parietina (Maritime sunburst lichen)	N	N	N	N	N	SI-N	N	N	SI-N	N	N	N
Alces americanus (Moose)	N	N	N	N	N	SI-N	SI	N	SI-N	N	N	N
Didelphis virginiana (Virginia opossum)	N	N	N	N	N	Inc-SI	N	N	N	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Lepus americanus (Snowshoe hare)	N	N	SI-N	N	N	SI-N	N	N	SI	N	GI	N
Lynx canadensis (Canada lynx)	N	N	N	N	N	SI-N	Inc-SI	N	N	N	GI-Inc	N
Microtus pinetorum (Woodland vole)	N	SI	SI	N	N	Inc-SI	N	N	N	N	N	N
Myotis septentrionalis (Northern myotis)	N	N	N	SI	N	Inc-SI-N	N	N	SI-N	N	N	SI-N
Perimyotis subflavusi (Tricolored bat)	N	N	N	SI-N	N	SI	N	N	SI	N	N	SI
Rangifer tarandus (Caribou, boreal population)	N	N	SI	N	N	SI-N	Inc	N	SI-N	Inc-SI	N	N
Scalopus aquaticus (Eastern mole)	N	SI	SI	N	N	SI	N	N	N	N	N	SI
Taxidea taxus (American badger)	N	SI	Inc	N	N	Inc	N	N	N	N	N	SI
Urocyon cinereoargenteus (Gray fox)	N	SI	SI	N	N	SI-N	N	N	N	N	N	N
Anguispira kochi (Banded globe)	N	GI	Inc-SI	N	SI	SI	N	N	SI-N	N	N	SI-N
Epioblasma torulosa rangiana (Northern riffleshell)	N	SI-N	SI	U	Inc-SI	Inc-SI	N	N	SI-N	Inc-SI	N	N
Epioblasma triquetra (Snuffbox)	N	SI-N	SI	U	Inc-SI	Inc-SI	N	N	SI-N	Inc-SI	N	N
Ligumia nasuta (Eastern pondmussel)	N	SI-N	SI	U	N	SI	N	N	Inc-SI	SI-N	N	N
Mesodon clausus (Yellow gobelet)	N	GI	GI-Inc	N	SI	SI	N	N	SI-N	N	N	SI-N
Simpsonaias ambigua (Salamander mussel)	N	SI-N	Inc-SI	N	GI	SI	N	N	Inc-SI-N	N	U	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Villosa fabalis (Rayed bean)	N	SI-N	Inc-SI	U	SI-N	Inc-SI	N	N	Inc-SI	Inc-SI	N	N
Chelydra serpentina (Snapping turtle)	N	N	SI	N	N	SI	N	N	SI-N	N	N	N
Clemmys guttata (Spotted turtle)	N	SI	Inc-SI	N	SI-N	Inc-SI	SI-N	SI-N	SI-N	N	N	N
Coluber constrictor foxii (Blue racer)	N	Inc	Inc	N	N	SI	N	N	SI-N	N	N	SI
Emydoidea blandingii (Blanding's turtle)	N	N	Inc-SI	N	N	SI	Inc-SI	N	Inc-SI	N	N	N
Glyptemys insculpta (Wood turtle)	N	SI-N	Inc-SI	SI	SI-N	SI	N	N	SI-N	SI-N	N	N
Graptemys geographica (Northern map turtle)	N	N	SI	N	N	SI	N	N	N	SI-N	N	N
Nerodia sipedon insularum (Lake Erie watersnake)	N	Inc-N	N	N	SI	SI	N	N	N	N	N	N
Opheodrys vernalis (Smooth greensnake)	N	N	Inc-SI	N	SI	SI	N	N	N	N	N	N
Pantherophis gloydi pop. 1 (Eastern foxsnake, Georgian Bay population)	N	SI	SI-N	N	N	SI	N	N	N	N	N	N
Pantherophis gloydi pop. 2 (Eastern foxsnake, Carolinian population)	N	N	Inc	U	SI-N	Inc-SI	N	N	SI	N	N	N
Pantherophis spiloides pop. 1 (Eastern ratsnake, Great Lakes - St. Lawrence population)	N	N	Inc-SI	N	N	SI	N	N	N	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Pantherophis spiloides pop. 2 (Eastern ratsnake, Carolinian population)	N	SI-N	GI	SI-N	N	Inc	N	N	N	N	N	N
Plestiodon fasciatus pop. 1 (Common Five-lined skink, Carolinian population)	N	SI-N	GI	SI	SI	Inc-SI	N	N	N	N	N	SI
Plestiodon fasciatus pop. 2 (Common Five-lined skink, southern Shield pop.)	N	N	N	N	SI	SI	N	N	N	N	N	N
Regina septemvittata (Queensnake)	N	SI	Inc-SI	N	SI	Inc-SI	N	N	SI-N	N	N	N
Thamnophis butleri (Butler's gartersnake)	N	N	Inc	N	N	SI	N	N	SI	N	N	N
Acer saccharum (Sugar maple)	N	SI	N	N	SI	SI	N	N	SI-N	N	N	N
Adenocaulon bicolor (Pathfinder)	N	Inc	N	U	SI	Inc	SI-N	N	N	N	N	N
Adoxa moschatellina (Muskroot)	N	N	N	U	SI	SI	N	N	SI	N	N	SI
Aplectrum hyemale (Puttyroot)	N	N	N	SI	N	Inc-SI	N	N	SI-N	N	N	SI-N
Asplenium ruta-muraria (Wallrue spleenwort)	N	N	N	N	Inc-SI	Inc	SI-N	N	N	N	N	Inc
Asplenium scolopendrium var. *americanum* (American hart's-tongue fern)	N	N	SI-N	N	N	Inc-SI	Inc	N	SI-N	N	SI-N	Inc

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Astragalus neglectus (Neglected milk-vetch)	N	N	SI	U	N	Inc-SI	N	N	N	N	N	SI
Aureolaria pedicularia (Fern-leaved false foxglove)	N	N	GI-Inc	N	Inc	SI	N	N	N	N	N	N
Azolla cristata (Eastern mosquito fern)	N	N	SI-N	U	SI-N	SI	N	N	N	N	N	N
Bartonia paniculata spp. *paniculata* (Branched bartonia)	N	SI-N	N	N	SI	SI	SI-N	N	Inc-SI	N	N	N
Botrychium ascendens (Upswept moonwort)	N	SI	N	N	SI	SI	SI-N	N	N	N	N	N
Botrychium pallidum (Pale moonwort)	N	SI	N	N	SI	SI-N	N	N	N	N	N	N
Botrychium spathulatum (Spatulate moonwort)	N	N	N	N	N	SI	N	N	N	SI-N	N	N
Bouteloua curtipendula (Side-oats grama)	N	N	Inc-SI	N	SI	SI	N	N	N	N	N	N
Carex aggregata (Glomerate sedge)	N	GI	Inc-SI	N	Inc-SI	SI	N	N	N	N	N	N
Carex alata (Broad-winged sedge)	N	Inc	SI-N	N	Inc-SI	Inc	N	N	Inc-SI	N	N	SI
Carex atratiformis (Black sedge)	N	Inc-SI	N	SI-N	SI-N	N	SI	SI-N	N	N	N	SI
Carex juniperorum (Juniper sedge)	N	N	GI-Inc	N	Inc-SI	SI	N	N	N	N	N	Inc
Carex loliacea (Ryegrass sedge)	N	N	N	N	SI	SI-N	SI	N	Inc-SI	N	N	N

PART 1

Species	Sea level	Natl barriers	Anth barriers	Land use change	Dispersal/movement	Hist. thermal niche	Physiol. thermal niche	Hist. hydrol. niche	Physiol. hydrol. niche	Disturbance	Ice/snow	Unc. geo. features
	B1	B2a	B2b	B3	C1	C2ai	C2aii	C2bi	C2bii	C2c	C2d	C3
Carex lupuliformis (False hop sedge)	N	N	GI-Inc	U	SI	Inc	N	N	Inc	SI	N	N
Carex nigromarginata (Black-edged sedge)	N	Inc	SI	N	SI	Inc	N	N	N	Inc-SI	U	U
Carex schweinitzii (Schweinitz's sedge)	N	N	SI	U	Inc-SI	SI	N	N	GI-Inc	N	N	N
Carex wiegandii (Wiegand's sedge)	N	N	N	N	SI	SI	SI	N	Inc	N	N	N
Carya laciniosa (Shellbark hickory)	N	N	Inc-SI	U	SI-N	SI	N	N	N	N	N	N
Castanea dentata (American chestnut)	N	N	GI-Inc	N	SI-N	Inc-SI	N	N	N	N	N	N
Celtis tenuifolia (Dwarf hackberry)	N	N	Inc	N	N	SI	N	N	N	N	N	N
Chamaenerion latifolium (River beauty)	N	GI-Inc	N	N	SI	N	GI	N	GI	N	U	SI
Chimaphila maculata (Spotted wintergreen)	N	N	SI	N	SI-N	Inc	N	N	N	N	N	U
Cirsium pitcheri (Pitcher's thistle)	N	SI-N	SI	U	Inc	Inc-SI	N	N	N	N	U	Inc
Conioselinum chinense (Chinese hemlock-parsley)	N	N	Inc	N	Inc-SI	SI	SI	N	SI	N	N	SI
Coptidium lapponicum (Lapland buttercup)	N	N	N	N	Inc-SI	N	Inc	N	SI	N	N	N
Cornus florida (Flowering dogwood)	N	N	Inc	U	N	Inc-SI	N	N	N	N	N	N
Cuscuta cephalanthi (Buttonbush dodder)	N	N	SI-N	N	Inc-SI	SI	N	N	Inc	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Cypripedium arietinum (Ram's-head lady's-slipper)	N	N	N	N	SI	SI	SI	N	SI-N	N	N	N
Cypripedium candidum (Small white lady's-slipper)	N	Inc-SI	GI-Inc	U	SI	SI	N	N	Inc	SI	N	SI-N
Cypripedium passerinum (Sparrow's-egg lady's-slipper)	N	N	N	N	N	SI	Inc-SI	N	N	N	N	N
Cystopteris laurentiana (Laurentian bladder fern)	N	N	N	U	SI-N	SI	N	N	N	N	N	SI
Cystopteris montana (Mountain bladder fern)	N	Inc-SI	N	U	SI-N	SI	SI	N	N	N	N	SI
Draba aurea (Golden draba)	N	Inc	N	N	SI	SI	SI	N	N	N	N	Inc
Dryas drummondii (Yellow mountain-avens)	N	GI	N	N	SI-N	SI	GI-Inc	N	N	N	N	SI
Eleocharis equisetoides (Horsetail spikerush)	N	SI	SI-N	U	SI	Inc	N	N	SI	SI	N	Inc-SI
Eleocharis geniculata (Bent spikerush)	N	SI	Inc	N	Inc-SI	Inc	N	N	GI-Inc	SI	N	Inc
Elymus lanceolatus ssp. *psammophilus* (Great Lakes wild rye)	N	SI-N	N	N	SI	SI	N	N	N	SI-N	N	Inc

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Enemion biternatum (False rue-anemone)	N	N	Inc	N	SI	Inc	N	N	N	N	N	N
Erigeron hyssopifolius (Daisy fleabane)	N	N	N	N	SI-N	SI-N	Inc	N	SI-N	SI	N	SI
Euphorbia commutata (Tinted woodland spurge)	N	N	SI-N	U	Inc-SI	SI	N	N	N	N	N	SI
Fraxinus nigra (Black ash)	N	N	N	N	SI-N	SI-N	N	N	Inc	N	N	N
Fraxinus profunda (Pumpkin ash)	N	N	Inc-SI	N	SI	Inc-SI	N	N	Inc-SI	N	N	N
Gentiana alba (White prairie gentian)	N	N	GI	N	SI	SI	N	N	N	N	N	N
Gratiola quartermaniae (Limestone hedge-hyssop)	N	SI	SI	SI	Inc	SI	N	N	SI-N	N	N	Inc
Gymnocarpium continentale (Nahanni oak fern)	N	N	N	N	N	SI-N	SI-N	N	N	N	N	Inc-SI
Hibiscus moscheutos (Swamp rose mallow)	N	SI-N	Inc-SI	U	N	Inc-SI	N	N	SI	U	N	N
Hudsonia tomentosa (Woolly beach-heath)	N	N	N	N	Inc-SI	SI	N	N	N	N	N	SI
Hydrastis canadensis (Goldenseal)	N	N	Inc	U	SI-N	Inc-SI	N	N	N	N	N	N
Hypericum prolificum (Shubby St. John's-wort)	N	N	Inc-SI	N	SI	SI	N	N	N	N	N	N

PART 1

Species	Sea level	Natl barriers	Anth barriers	Land use change	Dispersal/movement	Hist. thermal niche	Physiol. thermal niche	Hist. hydrol. niche	Physiol. hydrol. niche	Disturbance	Ice/snow	Unc. geo. features
	B1	B2a	B2b	B3	C1	C2ai	C2aii	C2bi	C2bii	C2c	C2d	C3
Iris brevicaulis (Short-stemmed iris)	N	GI	Inc-SI	N	SI	SI	N	N	Inc-SI	N	N	N
Iris lacustris (Dwarf lake iris)	N	N	N	U	Inc	Inc	N	N	N	N	N	SI
Isoetes engelmannii (Engelmann's quillwort)	N	N	SI	N	SI-N	SI	N	N	Inc	N	N	N
Isoetes tuckermanii (Tuckerman's quillwort)	N	N	N	N	SI	SI	N	N	SI	N	N	N
Isotria medeoloides (Small whorled pogonia)	N	N	GI	N	N	Inc	N	N	SI-N	N	N	SI
Juglans cinerea (Butternut)	N	N	SI-N	N	N	SI	N	N	N	N	N	SI
Justicia americana (American water-willow)	N	N	Inc-SI	N	SI-N	SI	N	N	SI	N	N	N
Lespedeza virginica (Slender bush-clover)	N	N	GI	N	SI-N	Inc	N	N	N	N	N	N
Linum striatum (Ridged yellow flax)	N	N	N	N	Inc-SI	SI	N	N	Inc-SI	N	N	N
Liparis liliifolia (Purple twayblade)	N	N	Inc-SI	N	N	N	N	N	N	N	N	N
Lupinus perennis (Sundial lupine)	N	N	SI	N	SI	Inc-SI	N	N	N	N	N	N
Magnolia acuminata (Cucumber magnolia)	N	N	Inc	N	N	Inc	N	N	SI-N	SI-N	N	N
Malaxis paludosa (Bog adder's-mouth)	N	N	N	N	SI-N	SI-N	Inc	N	GI-Inc	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Moehringia macrophylla (Large-leaved sandwort)	N	N	N	N	SI	SI-N	SI	N	N	N	N	SI
Muhlenbergia richardsonis (Mat muhly)	N	N	Inc-SI	U	SI	Inc	SI-N	N	SI-N	N	N	SI
Nelumbo lutea (American lotus)	N	SI-N	SI-N	N	N	SI	N	N	N	N	N	N
Nyssa sylvatica (Black gum)	N	N	SI-N	U	N	Inc	N	SI	SI-N	N	N	N
Oplopanax horridus (Devil's club)	N	GI	N	SI	SI	SI	Inc	N	SI-N	N	N	N
Opuntia fragilis (Brittle prickly-pear)	N	N	N	N	N	SI	N	N	N	N	N	N
Orobanche fasciculata (Clustered broomrape)	N	N	N	SI-N	N	SI	N	N	N	N	N	Inc-SI
Oxytropis splendens (Showy locoweed)	N	SI	N	N	SI	SI-N	SI-N	N	N	N	N	Inc-SI
Peltandra virginica (Green arrow arum)	N	N	SI	N	N	SI	N	N	SI	N	N	N
Phacelia franklinii (Franklin's phacelia)	N	N	N	N	Inc-SI	SI-N	N	N	N	N	N	N
Phacelia purshii (Miami-mist)	N	GI	Inc-SI	N	Inc-SI	SI	N	N	N	N	N	N
Picea glauca (White spruce)	N	N	N	N	N	SI	SI	N	N	N	N	N
Picea rubens (Red spruce)	N	SI	N	N	N	SI	Inc-SI	N	SI-N	N	N	N
Pinus rigida (Pitch pine)	N	N	SI	SI	N	SI	N	N	N	N	U	N
Pinus strobus (Eastern white pine)	N	SI	N	N	N	Inc-SI	N	N	N	N	U	N
Plantago cordata (Heart-leaved plantain)	N	N	GI-Inc	N	SI	Inc-SI	N	N	GI-Inc	U	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Platanthera grandiflora (Large purple fringed orchid)	N	N	SI-N	U	N	SI	N	N	Inc-SI	N	N	N
Platanthera leucophaea (Eastern prairie fringed orchid)	N	N	Inc	U	SI-N	SI	N	Inc	SI-N	N	N	U
Podostemum ceratophyllum (Horn-leaved riverweed)	N	N	SI-N	N	SI	SI-N	N	N	Inc-SI	SI	N	N
Polygala incarnata (Pink milkwort)	N	N	GI-Inc	N	SI	Inc	N	N	SI-N	N	N	N
Polystichum braunii (Braun's holly fern)	N	N	N	N	N	SI	SI	N	SI-N	N	N	N
Populus heterophylla (Swamp cottonwood)	N	N	GI	N	SI-N	SI	N	N	Inc-SI	N	N	N
Potamogeton hillii (Hill's pondweed)	N	N	N	N	SI	SI	SI	N	Inc	N	N	SI
Ptelea trifoliata (Common hoptree)	N	N	Inc	N	N	Inc-SI	N	N	N	N	N	SI
Pterospora andromedea (Woodland pinedrops)	N	N	N	N	N	SI	N	N	N	N	N	SI-N
Pyrola grandiflora (Arctic pyrola)	N	Inc	N	N	Inc	N	GI	N	N	N	GI	SI
Quercus ellipsoidalis (Northern pin oak)	N	N	SI-N	N	SI-N	SI	N	N	N	N	N	Inc-SI
Quercus ilicifolia (Bear oak)	N	SI	N	N	SI-N	SI	N	N	N	N	N	N

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Quercus muehlenbergii (Chinquapin oak)	N	N	SI-N	U	SI-N	Inc-SI	N	N	N	N	N	SI
Rhododendron canadense (Rhodora)	N	SI-N	SI	U	Inc-SI	SI	SI-N	N	SI	N	N	N
Rotala ramosior (Lowland toothcup)	N	N	N	N	SI-N	SI	N	N	Inc-SI	SI	N	N
Sassafras albidum (Sassafras)	N	N	SI-N	N	N	Inc-SI	N	N	N	N	N	N
Saxifraga oppositifolia (Purple mountain saxifrage)	N	Inc	N	N	Inc-SI	SI	GI-Inc	N	N	N	N	Inc
Saxifraga paniculata (Encrusted saxifrage)	N	Inc-SI	N	SI-N	Inc-SI	SI	SI	N	N	N	N	Inc-SI
Scleria verticillata (Low nutrush)	N	N	N	N	Inc-SI	Inc-SI	N	N	Inc-SI	SI	N	SI
Sida hermaphrodita (Virginia mallow)	N	N	Inc	U	SI	Inc-SI	N	N	SI-N	U	N	N
Silene acaulis (Moss campion)	N	GI	N	N	N	SI	GI	N	SI	Inc	N	SI
Smilax rotundifolia (Round-leaved greenbrier)	N	N	Inc	U	SI-N	SI	N	N	SI-N	N	N	N
Solidago houghtonii (Houghton's goldenrod)	N	SI	N	N	SI	SI	N	SI-N	N	N	N	Inc-SI
Solidago multiradiata (Multi-rayed goldenrod)	N	SI	N	N	SI-N	N	Inc	N	N	N	N	Inc

PART 1

Species	Sea level	Natl barriers	Anth barriers	Land use change	Dispersal/movement	Hist. thermal niche	Physiol. thermal niche	Hist. hydrol. niche	Physiol. hydrol. niche	Disturbance	Ice/snow	Unc. geo. features
	B1	B2a	B2b	B3	C1	C2ai	C2aii	C2bi	C2bii	C2c	C2d	C3
Solidago ulmifolia (Elm-leaved goldenrod)	N	GI	GI-Inc	N	SI	SI	N	N	N	N	N	N
Spiranthes magnicamporum (Great Plains ladies'-tresses)	N	N	N	N	SI	SI	N	N	N	SI-N	N	N
Sporobolus heterolepis (Prairie dropseed)	N	SI	SI	N	SI	SI	N	N	N	N	N	Inc-SI
Sporobolus rigidus var. *magnus* (Great Lakes sandreed)	N	N	N	N	SI	Inc-SI	N	N	N	SI	N	SI
Stylophorum diphyllum (Wood poppy)	N	N	GI-Inc	U	SI	Inc	N	N	N	N	N	N
Tephrosia virginiana (Virginia goat's-rue)	N	N	Inc-SI	N	Inc-SI	Inc	N	N	N	N	N	N
Tetraneuris herbacea (Lakeside daisy)	N	Inc-SI	SI	N	Inc-SI	Inc-SI	N	N	N	N	N	Inc
Triphora trianthophoros (Nodding pogonia)	N	N	GI	U	SI	Inc-SI	N	N	SI-N	N	N	N
Tsuga canadensis (Eastern hemlock)	N	N	SI	N	N	SI	SI-N	N	SI-N	SI	N	N
Vaccinium ovalifolium (Oval-leaved bilberry)	N	SI-N	N	SI-N	N	SI	SI	N	N	N	N	N
Valeriana edulis ssp. *ciliata* (Hairy valerian)	N	N	Inc	N	SI	Inc-SI	N	N	SI	N	N	SI

PART 1

Species	Sea level B1	Natl barriers B2a	Anth barriers B2b	Land use change B3	Dispersal/movement C1	Hist. thermal niche C2ai	Physiol. thermal niche C2aii	Hist. hydrol. niche C2bi	Physiol. hydrol. niche C2bii	Disturbance C2c	Ice/snow C2d	Unc. geo. features C3
Valeriana uliginosa (Swamp valerian)	N	N	N	N	SI	SI	SI	N	SI	N	N	N
Valerianella chenopodiifolia (Goosefoot cornsalad)	N	GI	N	N	GI-Inc	SI	N	N	N	N	N	SI-N
Viola striata (Striped cream violet)	N	N	SI	N	SI	Inc-SI	N	N	N	N	N	N
Woodsia alpina (Alpine woodsia)	N	N	N	N	N	SI-N	Inc	N	Inc	Inc-N	N	SI
Woodsia obtusa (Blunt-lobed woodsia)	N	N	N	N	N	SI	N	N	N	N	N	SI

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Ambystoma maculatum (Spotted salamander)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Anaxyrus fowleri (Fowler's toad)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Desmognathus fuscus (Northern dusky salamander)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Desmognathus ochrophaeus (Allegheny mountain dusky salamander)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Hemidactylium scutatum (Four-toed salamander)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Lithobates palustris (Pickerel frog)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Lithobates septentrionalis (Mink frog)	N	N	N/A	U	SI	U	U	U	U	U	U	U	U	U	U
Necturus maculosus (Mudpuppy)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Notophthalmus viridescens viridescens (Red-spotted newt)	N	N	N/A	U	U	U	U	U	U	U	U	U	U	U	U
Pseudacris crucifer (Spring peeper)	N	N	N/A	U	U	U	U	U	U	U	U	U	U	U	U
Pseudacris maculata (Boreal chorus frog)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Pseudacris triseriata pop. 1 (Western chorus frog, Great Lakes/St. Lawrence - Canadian Shield population)	N	N	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Pseudacris triseriata pop. 2 (Western chorus frog, Carolinian population)	N	N	N/A	U	U	U	U	U	U	U	U	U	U	U	U
Aix sponsa (Wood duck)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Anas discors (Blue-winged teal)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Anas rubripes (American black duck)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Antrostomus vociferus (Eastern whip-poor-will)	SI-N	SI-N	N/A	N	U	U	N	U	U	U	U	U	N	U	U
Asio flammeus (Short-eared owl)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Aythya collaris (Ring-necked duck)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Buteo lineatus (Red-shouldered hawk)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Butorides virescens (Green heron)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Cathartes aura (Turkey vulture)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Chaetura pelagica (Chimney swift)	N	N	N/A	N	U	U	N	U	U	U	N	U	U	U	U
Charadrius melodus (Piping plover)	N	N	N/A	N	U	U	N	U	Inc	N/A	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Colinus virginianus (Northern bobwhite)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Contopus cooperi (Olive-sided flycatcher)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Coturnicops noveboracensis (Yellow rail)	N	U	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Dolichonyx oryzivorus (Bobolink)	N	N	N/A	N	U	U	N	U	U	U	N	U	U	U	U
Empidonax virescens (Acadian flycatcher)	SI-N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Euphagus carolinus (Rusty blackbird)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Falco peregrinus (Peregrine falcon)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Hirundo rustica (Barn swallow)	N	N	N/A	N	U	U	N	U	U	U	N	U	U	U	U
Icteria virens (Yellow-breasted chat)	SI-N	N	N/A	N	U	U	N	U	U	U	U	U	N	U	U
Ixobrychus exilis (Least bittern)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Lanius ludovicianus (Loggerhead shrike)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Melanerpes erythrocephalus (Red-headed woodpecker)	SI-N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Meleagris gallopavo (Wild turkey)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Parkesia motacilla (Louisiana waterthrush)	SI-N	N	N/A	N	U	U	N	U	U	U	SI-N	U	U	U	U
Perisoreus canadensis (Gray jay)	N	N	N/A	N	U	U	N	U	N	N/A	Inc	U	U	U	U
Podilymbus podiceps (Pied-billed grebe)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Protonotaria citrea (Prothonotary warbler)	N	N	N/A	N	U	U	N	U	U	U	U	U	SI	SI	U
Rallus elegans (King rail)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Setophaga cerulea (Cerulean warbler)	SI	N	N/A	N	U	U	N	U	U	U	Inc	U	U	U	U
Setophaga citrina (Hooded warbler)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Setophaga discolor (Prairie warbler)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Setophaga kirtlandii (Kirtland's warbler)	U	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Sturnella magna (Eastern meadowlark)	N	N	N/A	N	U	U	N	U	U	U	SI-N	U	U	U	U
Tyto alba (Barn owl)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Vermivora chrysoptera (Golden-winged warbler)	N	N	N/A	N	U	U	Inc	U	U	U	U	SI	U	U	U
Amblyodon dealbatus (Short-toothed hump moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Aulacomnium acuminatum (Acutetip groove moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Bryoandersonia illecebra (Spoon-leaved moss)	N	N/A	U	N	U	U	N	U	U	U	U	U	U	U	U
Buxbaumia aphylla (Brown shield moss)	N	N/A	U	N	N	U	U	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Fissidens exilis (Pygmy pocket moss)	N	N/A	U	N	U	U	N	U	U	U	U	U	U	U	U
Marsupella sphacelata (Speckled rustwort)	N	N/A	U	N	N	N	U	U	U	U	U	U	U	U	U
Meesia uliginosa (Capillary thread moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Mielichhoferia mielichhoferiana (Alpine copper moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Mnium thomsonii (Thomson's leafy moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Oncophorus virens (Green spur moss)	N	N/A	U	N	N	N	U	U	U	U	U	U	U	U	U
Porella pinnata (Pinnate scalewort)	N	N/A	U	N	N	N	U	U	U	U	U	U	U	U	U
Rhytidiadelphus subpinnatus (Square gooseneck moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Sphagnum cuspidatum (Feathery peat moss)	N	N/A	U	N	N	N	U	U	U	U	U	U	U	U	U
Sphagnum platyphyllum (Flat-leaved peat moss)	N	N/A	U	N	N	N	U	U	U	U	U	U	U	U	U
Splachnum rubrum (Brilliant red dung moss)	SI	N/A	U	SI	U	U	N	U	U	U	U	U	U	U	U
Syntrichia cainii (Cain's screw moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Tetraplodon mnioides (Smooth-margin nitrogen moss)	SI	N/A	U	SI	N	N	N	U	U	U	U	U	U	U	U
Tetrodontium brownianum (Brown's four-toothed moss)	N	N/A	U	N	N	N	N	U	U	U	U	U	U	U	U
Tortula porteri (Porter's screw moss)	N	N/A	U	N	U	U	N	U	U	U	U	U	U	U	U
Acipenser fulvescens pop. 2 (Lake sturgeon, southern Hudson Bay/James Bay population)	N	N	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Acipenser fulvescens pop. 3 (Lake sturgeon, Great Lakes-upper St. Lawrence River population)	N	N	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Ammocrypta pellucida (Eastern sand darter)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Clinostomus elongatus (Redside dace)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Coregonus zenithicus (Shortjaw cisco)	N	N	N/A	N	U	U	N	N	N/A	N/A	U	U	U	U	U
Erimyzon sucetta (Lake chubsucker)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Esox americanus vermiculatus (Grass pickerel)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Exoglossum maxillingua (Cutlip minnow)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Fundulus notatus (Blackstripe topminnow)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Ichthyomyzon fossor (Northern brook lamprey)	N	N	N/A	N	U	U	N	U	U	U	U	U	SI	SI	U
Lepisosteus oculatus (Spotted gar)	N	N	N/A	N	U	U	N	SI	N/A	N/A	U	U	U	U	U
Lepomis gulosus (Warmouth)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Minytrema melanops (Spotted sucker)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Moxostoma carinatum (River redhorse)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Moxostoma duquesnei (Black redhorse)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Notropis photogenis (Silver shiner)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Noturus stigmosus (Northern madtom)	N	N	N/A	N	U	U	SI	U	U	U	U	U	U	U	U
Opsopoeodus emiliae (Pugnose minnow)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Percina copelandi (Channel darter)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Aeshna juncea (Sedge darner)	N	N	N/A	N	U	U	N	U	U	U	U	Inc	U	U	U
Amphiagrion saucium (Eastern red damsel)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Atrytonopsis hianna (Dusted skipper)	N	Inc	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Bombus affinis (Rusty-patched bumble Bee)	N	N	N/A	N	SI-N	U	U	U	U	U	U	U	U	U	U
Callophrys lanoraieensis (Bog elfin)	N	Inc	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Erora laeta (Early hairstreak)	N	Inc	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Erynnis martialis (Mottled duskywing)	N	Inc	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Gomphaeschna furcillata (Harlequin darner)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Lestes eurinus (Amber-winged spreadwing)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Nannothemis bella (Elfin skimmer)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Oarisma garita (Garita skipperling)	N	SI	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Pieris virginiensis (West Virginia white)	N	Inc	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Rhionaeschna mutata (Spatterdock darner)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Sphodros niger (Black purse web spider)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Trimerotropis huroniana (Lake Huron grasshopper)	N	SI-N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Williamsonia fletcheri (Ebony boghaunter)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Ahtiana aurescens (Eastern candlewax lichen)	N	N/A	N/A	N	N	N	N	U	U	U	U	U	U	U	U
Anaptychia crinalis (Hanging fringed lichen)	N	N/A	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Arthrorhaphis alpina (Alpine dot lichen)	N	N/A	N/A	N	N	N	U	U	U	U	U	U	U	U	U
Bryoria pikei (Pike's horsehair lichen)	SI	N/A	N/A	N	N	N	SI-N	U	U	U	U	U	U	U	U
Cetraria laevigata (Pin-striped Icelandmoss lichen)	N	N/A	N/A	N	N	N	N	U	U	U	U	U	U	U	U
Flavocetraria nivalis (Crinkled snow lichen)	N	N/A	N/A	N	N	N	N	U	U	U	U	U	U	U	U
Heppia adglutinata (Soil ruby lichen)	N	N/A	N/A	N	N	N	U	U	U	U	U	U	U	U	U
Leptogium corticola (Blistered jellyskin lichen)	SI	N/A	N/A	N	U	U	SI	U	U	U	U	U	U	U	U
Leptogium rivulare (Flooded jellyskin)	N	N/A	N/A	N	U	U	SI	U	U	U	U	U	U	U	U
Lobaria pulmonaria (Lungwort lichen)	N	N/A	N/A	N	U	U	SI-N	U	U	U	U	U	U	U	U
Parmotrema hypotropum (Southern powdered ruffle lichen)	N	N/A	N/A	N	N	N	SI-N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Physconia subpallida (Pale-bellied frost lichen)	N	N/A	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Pseudocyphellaria holarctica (Yellow specklebelly lichen)	N	N/A	N/A	N	U	U	SI	U	U	U	U	U	U	U	U
Punctelia appalachensis (Appalachian speckled shield lichen)	N	N/A	N/A	N	N	N	SI	U	U	U	U	U	U	U	U
Sticta beauvoisii (Fingered moon lichen)	N	N/A	N/A	N	N	N	Inc	U	U	U	U	U	U	U	U
Teloschistes chrysophthalmus pop. 1 (Golden-eye lichen, Great Lakes population)	N	N/A	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Thyrea confusa (Jelly-strap lichen)	N	N/A	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Usnea longissima (Methuselah's beard lichen)	N	N/A	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Xanthoria parietina (Maritime sunburst lichen)	N	N/A	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Alces americanus (Moose)	N	N	N/A	U	Inc	SI	U	U	U	U	U	U	U	U	U
Didelphis virginiana (Virginia opossum)	N	N	N/A	U	U	U	U	U	U	U	U	U	U	U	U

PART 2

	Other spp for habitat	Diet	Pollinators	Other spp disp	Pathogens/enemies	Competition	Other interspecific interaction	Genetic variation	Genetic bottleneck	Reproductive system	Phenol response	Doc response	Modeled change	Modeled overlap	Protected Areas
Species	**C4a**	**C4b**	**C4c**	**C4d**	**C4e**	**C4f**	**C4g**	**C5a**	**C5b**	**C5c**	**C6**	**D1**	**D2**	**D3**	**D4**
Lepus americanus (Snowshoe hare)	N	N	N/A	U	SI	U	U	U	U	U	U	U	U	U	U
Lynx canadensis (Canada lynx)	U	SI	N/A	U	U	SI	U	SI	N/A	N/A	U	SI	U	U	U
Microtus pinetorum (Woodland vole)	N	U	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Myotis septentrionalis (Northern myotis)	N	N	N/A	N	Inc-SI	N	N	U	U	U	U	U	U	U	U
Perimyotis subflavusi (Tricolored bat)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Rangifer tarandus (Caribou, boreal pop.)	Inc	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Scalopus aquaticus (Eastern mole)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Taxidea taxus (American badger)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Urocyon cinereoargenteus (Gray fox)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Anguispira kochi (Banded globe)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Epioblasma torulosa rangiana (Northern riffleshell)	N	N	N/A	Inc-SI	U	U	N	U	U	U	U	U	U	U	U
Epioblasma triquetra (Snuffbox)	N	N	N/A	Inc-SI	U	U	N	U	U	U	U	U	U	U	U
Ligumia nasuta (Eastern pondmussel)	N	N	N/A	SI-N	U	U	U	U	U	U	U	U	U	U	U
Mesodon clausus (Yellow gobelet)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Simpsonaias ambigua (Salamander mussel)	Inc	N	N/A	Inc	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Villosa fabalis (Rayed bean)	N	N	N/A	SI-N	U	U	N	U	U	U	U	U	U	U	U
Chelydra serpentina (Snapping turtle)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Clemmys guttata (Spotted turtle)	N	N	N/A	N	U	U	N	N	N/A	N/A	U	U	U	U	U
Coluber constrictor foxii (Blue racer)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Emydoidea blandingii (Blanding's turtle)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Glyptemys insculpta (Wood turtle)	N	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U
Graptemys geographica (Northern map turtle)	N	SI-N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Nerodia sipedon insularum (Lake Erie watersnake)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Opheodrys vernalis (Smooth greensnake)	N	N	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Pantherophis gloydi pop. 1 (Eastern foxsnake, Georgian Bay population)	N	N	N/A	U	U	U	U	SI	N/A	N/A	U	U	U	U	U
Pantherophis gloydi pop. 2 (Eastern foxsnake, Carolinian population)	N	N	N/A	U	U	U	U	U	SI	N/A	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Pantherophis spiloides pop. 1 (Eastern ratsnake, Great Lakes - St. Lawrence population)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Pantherophis spiloides pop. 2 (Eastern ratsnake, Carolinian population)	N	N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Plestiodon fasciatus pop. 1 (Common five-lined skink, Carolinian population)	N	N	N/A	N	U	U	N	SI	N/A	N/A	U	U	U	U	U
Plestiodon fasciatus pop. 2 (Common five-lined skink, southern Shield population)	N	N	N/A	N	U	U	N	SI	N/A	N/A	U	U	U	U	U
Regina septemvittata (Queensnake)	N	SI	N/A	N	U	U	U	U	U	U	U	U	U	U	U
Thamnophis butleri (Butler's gartersnake)	SI-N	SI-N	N/A	N	U	U	N	U	U	U	U	U	U	U	U
Acer saccharum (Sugar maple)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Adenocaulon bicolor (Pathfinder)	N	N/A	N	N	U	N	U	U	U	U	U	U	U	U	U
Adoxa moschatellina (Muskroot)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Aplectrum hyemale (Puttyroot)	N	N/A	SI-N	N	U	U	SI-N	U	U	U	U	U	U	U	U
Asplenium ruta-muraria (Wallrue spleenwort)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Asplenium scolopendrium var. *americanum* (American hart's-tongue fern)	SI-N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Astragalus neglectus (Neglected milk-vetch)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Aureolaria pedicularia (Fern-leaved false foxglove)	N	N/A	N	N	U	U	Inc-SI	U	U	U	U	U	U	U	U
Azolla cristata (Eastern mosquito fern)	N	N/A	N	SI-N	N	N	U	U	U	U	U	U	U	U	U
Bartonia paniculata spp. *paniculata* (Branched bartonia)	N	N/A	N	N	U	U	SI-N	U	U	U	U	U	U	U	U
Botrychium ascendens (Upswept moonwort)	N	N/A	N	N	U	U	SI	SI	N/A	N/A	U	U	U	U	U
Botrychium pallidum (Pale moonwort)	N	N/A	U	N	SI	N	SI	U	U	U	U	U	U	U	U
Botrychium spathulatum (Spatulate moonwort)	N	N/A	N	N	U	U	SI	U	U	U	U	U	U	U	U
Bouteloua curtipendula (Side-oats grama)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Carex aggregata (Glomerate sedge)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Carex alata (Broad-winged sedge)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Carex atratiformis (Black sedge)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Carex juniperorum (Juniper sedge)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Carex loliacea (Ryegrass sedge)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Carex lupuliformis (False hop sedge)	N	N/A	N	N	N	SI-N	N	U	U	U	U	U	U	U	U
Carex nigromarginata (Black-edged sedge)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Carex schweinitzii (Schweinitz's sedge)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Carex wiegandii (Wiegand's sedge)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Carya laciniosa (Shellbark hickory)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Castanea dentata (American chestnut)	N	N/A	N	N	Inc	N	N	U	U	U	U	U	U	U	U
Celtis tenuifolia (Dwarf hackberry)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Chamaenerion latifolium (River beauty)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Chimaphila maculata (Spotted wintergreen)	N	N/A	SI-N	N	U	U	SI-N	U	U	U	U	U	U	U	U
Cirsium pitcheri (Pitcher's thistle)	SI	N/A	N	N	U	U	N	Inc	N/A	N/A	U	U	U	U	U
Conioselinum chinense (Chinese hemlock-parsley)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Coptidium lapponicum (Lapland buttercup)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Cornus florida (Flowering dogwood)	N	N/A	N	N	Inc	N	N	U	U	U	U	U	U	U	U
Cuscuta cephalanthi (Buttonbush dodder)	SI	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Cypripedium arietinum (Ram's-head lady's-slipper)	N	N/A	SI-N	N	N	N	SI	SI	N/A	N/A	U	U	U	U	U
Cypripedium candidum (Small white lady's-slipper)	N	N/A	N	N	N	U	SI	U	U	U	U	U	U	U	U
Cypripedium passerinum (Sparrow's-egg lady's-slipper)	N	N/A	N	N	N	N	SI	U	U	U	U	U	U	U	U
Cystopteris laurentiana (Laurentian bladder fern)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Cystopteris montana (Mountain bladder fern)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Draba aurea (Golden draba)	N	N/A	U	N	N	N	U	U	U	U	U	U	U	U	U
Dryas drummondii (Yellow mountain-avens)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Eleocharis equisetoides (Horsetail spikerush)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Eleocharis geniculata (Bent spikerush)	N	N/A	N	N	N	Inc-SI	N	U	U	U	U	U	U	U	U
Elymus lanceolatus ssp. *psammophilus* (Great Lakes wild rye)	N	N/A	N	N	N	U	U	U	U	U	U	U	U	U	U
Enemion biternatum (False rue-anemone)	N	N/A	N	SI-N	U	U	N	U	U	U	U	U	U	U	U
Erigeron hyssopifolius (Daisy fleabane)	N	N/A	N	U	N	N	U	U	U	U	U	U	U	U	U
Euphorbia commutata (Tinted woodland spurge)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Fraxinus nigra (Black ash)	N	N/A	N	N	Inc	N	N	U	U	U	U	U	U	U	U
Fraxinus profunda (Pumpkin ash)	N	N/A	N	N	SI	U	N	U	U	U	U	U	U	U	U
Gentiana alba (White prairie gentian)	N	N/A	SI	N	U	U	N	U	U	U	U	U	U	U	U
Gratiola quartermaniae (Limestone hedge-hyssop)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Gymnocarpium continentale (Nahanni oak fern)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Hibiscus moscheutos (Swamp rose mallow)	N	N/A	SI-N	N	U	U	N	U	U	U	U	U	U	U	U
Hudsonia tomentosa (Woolly beach-heath)	N	N/A	U	N	U	U	N	U	U	U	U	U	U	U	U
Hydrastis canadensis (Goldenseal)	N	N/A	N	N	N	SI-N	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Hypericum prolificum (Shubby St. John's-wort)	N	N/A	N	U	U	U	U	U	U	U	U	U	U	U	U
Iris brevicaulis (Short-stemmed iris)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Iris lacustris (Dwarf lake iris)	N	N/A	N	N	U	N	U	SI	N/A	N/A	U	U	U	U	U
Isoetes engelmannii (Engelmann's quillwort)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Isoetes tuckermanii (Tuckerman's quillwort)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Isotria medeoloides (Small whorled pogonia)	N	N/A	U	N	U	U	SI	U	U	U	U	U	U	U	U
Juglans cinerea (Butternut)	N	N/A	N	N	SI	U	N	SI	N/A	N/A	U	U	U	U	U
Justicia americana (American water-willow)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Lespedeza virginica (Slender bush-clover)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Linum striatum (Ridged yellow flax)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Liparis liliifolia (Purple twayblade)	N	N/A	N	N	U	U	SI	U	U	U	U	U	U	U	U
Lupinus perennis (Sundial lupine)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	C4a Other spp for habitat	C4b Diet	C4c Pollinators	C4d Other spp disp	C4e Pathogens/enemies	C4f Competition	C4g Other interspecific interaction	C5a Genetic variation	C5b Genetic bottleneck	C5c Reproductive system	C6 Phenol response	D1 Doc response	D2 Modeled change	D3 Modeled overlap	D4 Protected Areas
Magnolia acuminata (Cucumber magnolia)	N	N/A	SI-N	N	U	U	N	U	U	U	U	U	U	U	U
Malaxis paludosa (Bog adder's-mouth)	N	N/A	U	N	U	U	SI	U	U	U	U	U	U	U	U
Moehringia macrophylla (Large-leaved sandwort)	N	N/A	N	N	N	N	U	SI-N	N/A	N/A	U	U	U	U	U
Muhlenbergia richardsonis (Mat muhly)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Nelumbo lutea (American lotus)	N	N/A	N	N	U	U	U	U	U	U	U	U	U	U	U
Nyssa sylvatica (Black gum)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Oplopanax horridus (Devil's club)	N	N/A	N	U	U	U	U	U	U	U	U	U	U	U	U
Opuntia fragilis (Brittle prickly-pear)	N	N/A	U	N	U	U	U	U	U	U	U	U	U	U	U
Orobanche fasciculata (Clustered broomrape)	N	N/A	N	N	U	U	Inc-SI	U	U	U	U	U	U	U	U
Oxytropis splendens (Showy locoweed)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Peltandra virginica (Green arrow arum)	N	N/A	SI	N	U	U	N	U	U	U	U	U	U	U	U
Phacelia franklinii (Franklin's phacelia)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Phacelia purshii (Miami-mist)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Picea glauca (White spruce)	N	N/A	N	N	SI	N	U	U	U	U	U	U	U	U	U
Picea rubens (Red spruce)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Pinus rigida (Pitch pine)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Pinus strobus (Eastern white pine)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Plantago cordata (Heart-leaved plantain)	N	N/A	N	N	N	U	U	U	U	U	U	U	U	U	U
Platanthera grandiflora (Large purple fringed orchid)	N	N/A	SI-N	N	U	U	SI	U	U	U	U	U	U	U	U
Platanthera leucophaea (Eastern prairie fringed orchid)	N	N/A	SI	N	U	U	SI	U	U	U	U	U	U	U	U
Podostemum ceratophyllum (Horn-leaved riverweed)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Polygala incarnata (Pink milkwort)	N	N/A	N	SI-N	N	SI	U	U	U	U	U	U	U	U	U
Polystichum braunii (Braun's holly fern)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Populus heterophylla (Swamp cottonwood)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Potamogeton hillii (Hill's pondweed)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Ptelea trifoliata (Common hoptree)	N	N/A	N	N	N	U	U	U	U	U	U	U	U	U	U
Pterospora andromedea (Woodland pinedrops)	Inc	N/A	N	N	SI-N	Inc-SI	U	U	U	U	U	U	U	U	U
Pyrola grandiflora (Arctic pyrola)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Quercus ellipsoidalis (Northern pin oak)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Quercus ilicifolia (Bear oak)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Quercus muehlenbergii (Chinquapin oak)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Rhododendron canadense (Rhodora)	SI	N/A	N	N	U	U	SI	U	U	U	U	U	U	U	U
Rotala ramosior (Lowland toothcup)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Sassafras albidum (Sassafras)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Saxifraga oppositifolia (Purple mountain saxifrage)	N	N/A	U	N	N	U	U	U	U	U	U	U	U	U	U
Saxifraga paniculata (Encrusted saxifrage)	N	N/A	U	N	U	U	N	U	U	U	U	U	U	U	U
Scleria verticillata (Low nutrush)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Sida hermaphrodita (Virginia mallow)	N	N/A	U	N	N	SI	N	U	U	U	U	U	U	U	U
Silene acaulis (Moss campion)	N	N/A	U	N	U	U	N	U	U	U	U	U	U	U	U
Smilax rotundifolia (Round-leaved greenbrier)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Solidago houghtonii (Houghton's goldenrod)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Solidago multiradiata (Multi-rayed goldenrod)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Solidago ulmifolia (Elm-leaved goldenrod)	N	N/A	N	N	N	N	N	U	U	U	U	U	U	U	U
Spiranthes magnicamporum (Great Plains ladies'-tresses)	N	N/A	N	N	N	N	SI	U	U	U	U	U	U	U	U
Sporobolus heterolepis (Prairie dropseed)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Sporobolus rigidus var. *magnus* (Great Lakes sandreed)	N	N/A	N	N	N	U	U	U	U	U	U	U	U	U	U
Stylophorum diphyllum (Wood poppy)	N	N/A	N	N	U	SI	U	U	U	U	U	U	U	U	U
Tephrosia virginiana (Virginia goat's-rue)	N	N/A	N	U	N	N	N	U	U	U	U	U	U	U	U
Tetraneuris herbacea (Lakeside daisy)	U	N/A	N	N	U	U	N	N	N/A	N/A	U	U	U	U	U
Triphora trianthophoros (Nodding pogonia)	N	N/A	N	N	SI	Inc	SI	U	U	U	U	U	U	U	U
Tsuga canadensis (Eastern hemlock)	N	N/A	N	N	Inc-SI	N	U	U	U	U	U	U	U	U	U
Vaccinium ovalifolium (Oval-leaved bilberry)	N	N/A	N	N	N	N	U	U	U	U	U	U	U	U	U
Valeriana edulis ssp. *ciliata* (Hairy valerian)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Valeriana uliginosa (Swamp valerian)	U	N/A	N	N	N	U	U	U	U	U	U	U	U	U	U

PART 2

Species	Other spp for habitat C4a	Diet C4b	Pollinators C4c	Other spp disp C4d	Pathogens/enemies C4e	Competition C4f	Other interspecific interaction C4g	Genetic variation C5a	Genetic bottleneck C5b	Reproductive system C5c	Phenol response C6	Doc response D1	Modeled change D2	Modeled overlap D3	Protected Areas D4
Valerianella chenopodiifolia (Goosefoot cornsalad)	N	N/A	N	N	U	U	U	U	U	U	U	U	U	U	U
Viola striata (Striped cream violet)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U
Woodsia alpina (Alpine woodsia)	N	N/A	N	N	U	U	U	U	U	U	U	U	U	U	U
Woodsia obtusa (Blunt-lobed woodsia)	N	N/A	N	N	U	U	N	U	U	U	U	U	U	U	U

(.1k P.R. 18 07 30)
ISBN 978-1-4868-2386-4 (print)
ISBN 978-1-4868-2387-1 (pdf)