Ministry of Natural Resources

31

CLIMATE CHANGE RESEARCH REPORT CCRR-31

Responding to Climate Change Through Partnership

The Vulnerability of Provincially Rare Species (Species-at-Risk) to Climate Change in the Lake Simcoe Watershed, Ontario, Canada

Ontario

Sustainability in a Changing Climate: An Overview of MNR's Climate Change Strategy (2011-2014)

Climate change will affect all MNR programs and the natural resources for which it has responsibility. This strategy confirms MNR's commitment to the Ontario government's climate change initiatives such as the Go Green Action Plan on Climate Change and outlines research and management program priorities for the 2011-2014 period.

Theme 1: Understand Climate Change

MNR will gather, manage, and share information and knowledge about how ecosystem composition, structure and function – and the people who live and work in them – will be affected by a changing climate. Strategies:

- Communicate internally and externally to build awareness of the known and potential impacts of climate change and mitigation and adaptation options available to Ontarians.
- Monitor and assess ecosystem and resource conditions to manage for climate change in collaboration with other agencies and organizations.
- Undertake and support research designed to improve understanding of climate change, including improved temperature and precipitation projections, ecosystem vulnerability assessments, and improved models of the carbon budget and ecosystem processes in the managed forest, the settled landscapes of southern Ontario, and the forests and wetlands of the Far North.
- Transfer science and understanding to decision-makers to enhance comprehensive planning and management in a rapidly changing climate.

Theme 2: Mitigate Climate Change

MNR will reduce greenhouse gas emissions in support of Ontario's greenhouse gas emission reduction goals. Strategies:

- Continue to reduce emissions from MNR operations though vehicle fleet renewal, converting to other high fuel efficiency/low-emissions equipment, demonstrating leadership in energy-efficient facility development, promoting green building materials and fostering a green organizational culture.
- Facilitate the development of renewable energy by collaborating with other Ministries to promote the value of Ontario's resources as potential green energy sources, making Crown land available for renewable energy development, and working with proponents to ensure that renewable energy developments are consistent with approval requirements and that other Ministry priorities are considered.
- Provide leadership and support to resource users and industries to reduce carbon emissions and increase carbon storage by undertaking afforestation, protecting natural heritage areas, exploring opportunities for forest carbon management to increase carbon uptake, and promoting the increased use of wood products over energy-intensive, non-renewable alternatives.
- Help resource users and partners participate in a carbon offset market, by working with our partners to ensure that a robust trading system is in place based on rules established in Ontario (and potentially in other jurisdictions), continuing to examine the mitigation potential of forest carbon management in Ontario, and participating in the development of protocols and policies for forest and land-based carbon offset credits.

Theme 3: Help Ontarians Adapt

MNR will provide advice and tools and techniques to help Ontarians adapt to climate change. Strategies include:

- Maintain and enhance emergency management capability to protect life and property during extreme events such as flooding, drought, blowdown and wildfire.
- Use scenarios and vulnerability analyses to develop and employ adaptive solutions to known and emerging issues.
- Encourage and support industries, resource users and communities to adapt, by helping to develop understanding and capabilities of partners to adapt their practices and resource use in a changing climate.
- Evaluate and adjust policies and legislation to respond to climate change challenges.

The Vulnerability of Provincially Rare Species (Species-at-Risk) to Climate Change in the Lake Simcoe Watershed, Ontario, Canada

Samuel R. Brinker and Colin Jones

Natural Heritage Information Centre, Science and Information Branch, Ontario Ministry of Natural Resources, 300 Water St. N., Peterborough, ON, Canada, K9J 8M5

2012

Science and Information Resources Division • Ontario Ministry of Natural Resources

Library and Archives Canada Cataloguing in Publication Data

Brinker, Samuel R.
The vulnerability of provincially rare species (species at risk) to climate change in the Lake Simcoe Watershed, Ontario, Canada [electronic resource] / Sam Brinker and Colin Jones.

(Climate change research report ; CCRR-31)
Electronic monograph in PDF format.
Issued also in printed form.
Includes some text in French.
Includes bibliographical references.
ISBN: 978-1-4606-0578-3

1. Endangered species – Climatic factors – Ontario – Simcoe, Lake, Watershed. 2. Endangered species – Effect of habitat modifications on - Ontario –Simcoe, Lake, Watershed. 3. Wildlife conservation – Ontario – Simcoe, Lake, Watershed. 4. Climatic changes – Environmental aspects – Ontario – Simcoe, Lake, Watershed. I. Jones, Colin D. (Colin David), 1969 – II. Ontario. Ministry of Natural Resources. Applied Research and Development Branch. III. Title. IV. Series: Climate change research report (Online) ; CCRR-31.

QL84.26 O5 B74 2012 333.95'420971317 C2012-964027-1

Printed in Ontario, Canada

Single copies of this publication
are available from:

Applied Research and Development
Ontario Forest Research Institute
Ministry of Natural Resources
1235 Queen Street East
Sault Ste. Marie, ON
Canada P6A 2E5

Telephone: (705) 946-2981
Fax: (705) 946-2030
E-mail: information.ofri@ontario.ca

Cette publication hautement spécialisée *The Vulnerability of Provincially Rare Species (Species at Risk) to Climate Change in the Lake Simcoe Watershed, Ontario, Canada* n'est disponible qu'en Anglais en vertu du Règlement 411/97 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 de Richesses naturelles au information.ofri@ontario.ca.

This paper contains recycled materials.

Summary

An important precursor to creating natural resource management adaptation strategies in a rapidly changing climate is to identify the vulnerability of selected assets in a study area. We used NatureServe's Climate Change Vulnerability Index (CCVI) on a subset of provincially rare species inhabiting the Lake Simcoe watershed, Ontario, Canada, to identify species that are potentially vulnerable to climate change. Of the 62 provincially rare species known to inhabit the watershed, we completed vulnerability assessments for 17 high priority species. Of those species, six were identified as vulnerable. Redside dace (*Clinostomus elongatus)* was scored as extremely vulnerable, followed by Schweinitz's sedge (*Carex schweinitzii),* which was scored as highly vulnerable. American ginseng (*Panax quinquefolius*), eastern prairie fringed-orchid (*Platanthera leucophaea)*, ram's-head lady's-slipper (*Cypripedium arietinum)* and Jefferson salamander (*Ambystoma jeffersonianum)* were all scored as moderately vulnerable species. Key vulnerabilities associated with many of these species in the Lake Simcoe watershed included their specialized life history requirements, limited dispersal capabilities coupled with many barriers to movement, restricted distribution, high degree of habitat specialization, and specific physiological requirements related to temperature and moisture. We propose that more systematic and complete baseline data be collected for these species across their range within the study area as a basis for future quantitative monitoring. We suggest that the vulnerabilities of each species be integrated with other known stressors, and that adaptive measures focus on reducing vulnerabilities that affect multiple species to maximize efficiency.

Résumé

La vulnérabilité aux changements climatiques des espèces rares (espèces en péril) du bassin versant du lac Simcoe (Ontario) Canada

Un élément préalable important à l'élaboration de stratégies d'adaptation pour la gestion des ressources naturelles dans un climat en rapide évolution consiste à déterminer la vulnérabilité de certaines espèces de la zone étudiée. Nous avons utilisé le NatureServe's Climate Change Vulnerability Index (CCVI) pour un sous-ensemble d'espèces rares de la province du bassin versant du lac Simcoe (Ontario) Canada, pour recenser les espèces possiblement vulnérables aux changements climatiques. Nous avons évalué la vulnérabilité de 17 des 62 espèces rares de la province connues pour habiter le bassin versant et jugées prioritaires. De ces espèces, 6 ont été jugées vulnérables. Le méné long (*Clinostomus elongatus)* a été classé comme extrêmement vulnérable, suivi du carex de Schweinitz (*Carex schweinitzii)* qui a été classé hautement vulnérable. Le ginseng à cinq folioles (*Panax quinquefolius*), la platanthère blanchâtre de l'Est (*Platanthera leucophaea)*, le cypripède tête-de-bélier (*Cypripedium arietinum)* et la salamandre de Jefferson (*Ambystoma jeffersonianum)* ont été classés comme des espèces modérément vulnérables. Les principaux éléments de vulnérabilité de nombreuses espèces du bassin versant du lac Simcoe étaient notamment leurs exigences particulières longuement reconnues, leur capacité limitée de se disperser et les nombreux obstacles à leur mouvement et à leur propagation, le haut degré de particularité de leur habitat, de même que certaines exigences physiologiques de température et d'humidité. Nous proposons qu'une plus vaste base de données systématiques et complètes soit constituée sur ces espèces sur l'étendue du secteur de l'étude pour servir à la surveillance quantitative. Pour maximiser l'efficacité de l'étude, nous proposons que les vulnérabilités de chaque espèce soient intégrées à d'autres facteurs de stress connus et que les mesures d'adaptation portent sur la réduction des vulnérabilités qui nuisent aux espèces.

Acknowledgements

We thank Bruce Young, NatureServe, for assistance with the Climate Change Vulnerability Index tool and for providing advice and guidance on interpreting results. We thank Paul Gray, Lisa Buse, and Wasyl Bakowsky for reviewing an earlier version of the manuscript. We thank Trudy Vaittinen for report production assistance. This project was funded by the Climate Change Program, Ontario Ministry of Natural Resources, with in-kind contributions from the Natural Heritage Information Centre.

Foreword

This is one in a series of reports to help resource managers evaluate the vulnerability of natural assets to climate change. Given that vulnerability assessment techniques continue to evolve, it is important for resource managers to learn by doing and to pass on knowledge gained to support MNR and others engaged in adaptive management. Accordingly, the vulnerability assessment reports included in the Climate Change Research Report Series have been prepared using the best available information under the circumstances (e.g., time, financial support, and data availability). Collectively, these assessments can inform decisionmaking, enhance scientific understanding of how natural assets respond to climate change, and help resource management organizations establish research and monitoring needs and priorities.

Cameron Mack

Acting Director, Applied Research and Development Branch

Contents

Introduction

Certain species considered provincially rare in the Lake Simcoe watershed including some listed as threatened or endangered under Ontario's *Endangered Species Act* (Statutes of Ontario 2007), may be at risk of extirpation due to adverse effects of natural and/or anthropogenic stressors. Climate change, acting alone or in combination with other stressors, may pose an important emerging threat for many of these species. Several tools to assess climate change effects are being developed for use by resource managers to categorize the relative vulnerability of selected species to climate change.

In response to the Lake Simcoe Protection Plan (Goverment of Ontario 2009), Ontario's Adaptation Strategy and Action Plan: 2011-2014 (Government of Ontario 2011), and the Ministry of Natural Resources' Climate Change Strategy (MNR 2011), vulnerability assessments have been completed for selected natural assests in the Lake Simcoe watershed. As part of that initative, we tested the utility of the climate change vulnerability index (CCVI) developed by NatureServe (Young et al. 2010) on a subset of provincially rare species occurring in the Lake Simcoe watershed. This vulnerability index was chosen because it is rapid, has been through extensive peer review, works for plants and animals (both terrestrial and aquatic species), is described in guidelines for ecologists completing assessments, and is already in use or being tested in 10 jurisdictions in the United States. The CCVI indicates whether a species in the assessment area is likely to undergo range contraction or expansion, or experience other population changes. By testing the model against a subset of high priority provincially rare species found within the Lake Simcoe watershed our objectives were to:

- categorize the relative vulnerability of each species
- identify species-level indicators that are useful for assessing vulnerability to climate change
- identify the key factors causing species vulnerability.

Methods

Study area

The Lake Simcoe watershed encompasses about 330,000 ha (Figure 1) located in south-central Ontario. Primary land uses in the watershed include agriculture (~47% of the watershed area), and urban infrastructure and transportation corridors (~18%) (MOE et al. 2009). Fragmented patches of natural cover (~35%) account for the remainder of the area. The cumulative length of the 35 rivers that flow into Lake Simcoe is about 4,000 km; these include the Holland River, Beaver River, Pefferlaw River, and Uxbridge Brook. The main lake in the watershed, Lake Simcoe, is the most intensively fished (open water and ice fishing) inland lake in Ontario. Many species that occur in the watershed are classified as rare or as species-at-risk and invasive species are an ever-growing concern. Five provincial parks (Sibbald Point, Mara, McRae Point, Holland Landing, and Duclos Point) and several other natural heritage areas are established in the watershed. The largest communities in the watershed area Orillia and Barrie, with populations of about 30,500 and 135,000, respectively.

Species selection

For our assessment, species were selected if they were provincially rare, that is have a provincial status rank (Srank) of possibly extirpated (SH), critically imperilled (S1), imperilled (S2), or vulnerable (S3) as designated by the MNR's Natural Heritage Information Centre (NHIC). While these rankings are not legal designations, many of these species also have official status and protection under Ontario's *Endangered Species Act*. A Geographic Information System (GIS) was used to generate a complete list of all known provincially rare species in the study area using occurrence records stored in the NHIC's provincial database (NHIC 2010). An element occurrence base layer was overlain on the study area map to determine the presence of provincially rare species (Figure 2). The final list contained 62 provincially rare species. To select species as potential indicators of vulnerability to

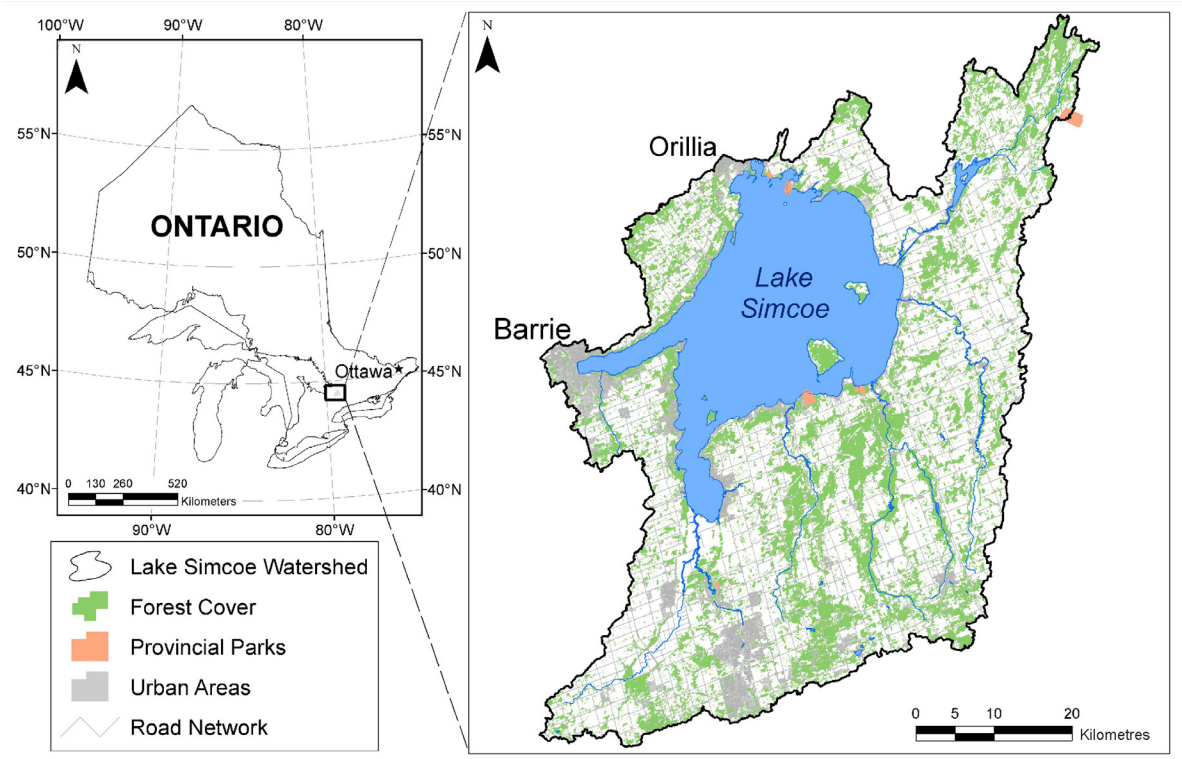

Figure 1. *Location of the Lake Simcoe watershed within the province of Ontario.*

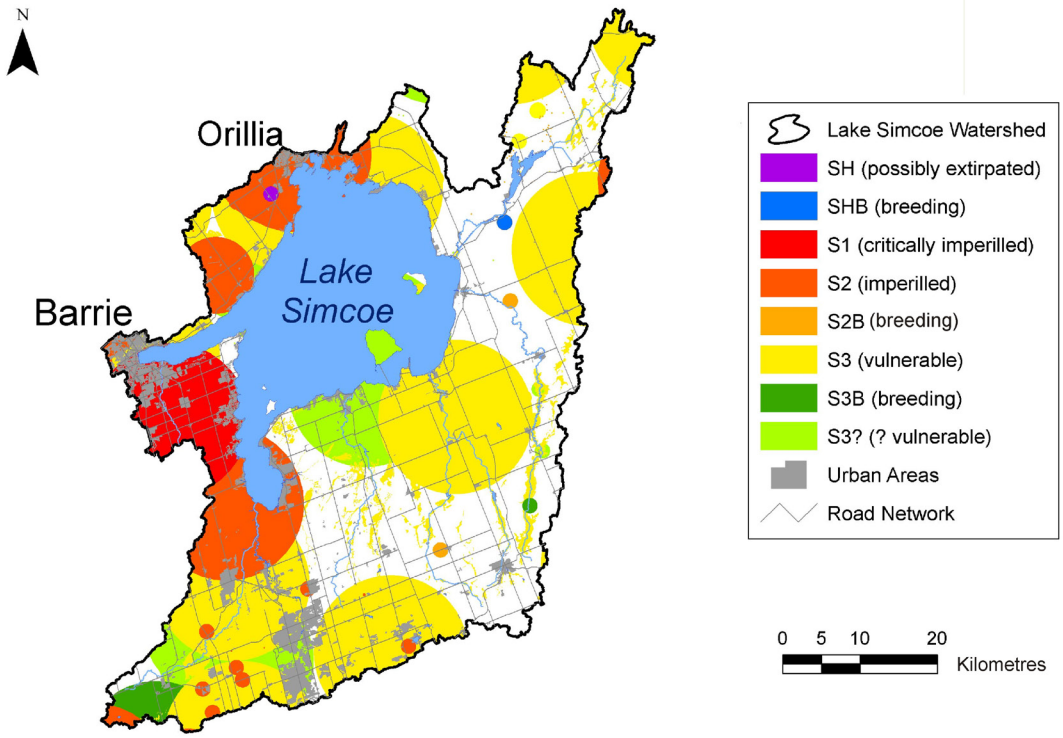

Figure 2. *Distribution of provincially rare species (represented as buffered polygons the size of which depend on known location accuracy) arranged by provincial rank (Srank) in the Lake Simcoe watershed.*

climate change, each species was assigned a rank of high, medium, or low sensitivity based on several qualitative criteria (see Appendix). Table 1 provides the priority score and the associated criteria used to rank each species. In addition, we selected particular species to ensure that a variety of taxonomic groups (i.e., birds, fish, reptiles, amphibians, insects, and vascular plants), and habitat preferences (i.e., aquatic, semi-aquatic, and terrestrial) were represented in the analysis.

Seventeen of the 62 species were identified as high priority and were selected as potential indicators of climate change to assess using the CCVI tool. Table 2 highlights the priority species and their relative conservation status rank.

Table 1. *Criteria used to rank the 62 provincially rare species in the Lake Simcoe watershed.*

Priority	Criteria
High	Recent, substantiated records of occurrence from the Lake Simcoe watershed
	Species at risk in Canada and/or Ontario
	Sufficient literature available
	Globally rare
	At northern or southern range limit
	Specialized habitat or life history requirements
Medium	Provincially rare and widespread
	Lack information pertaining to Ontario
	Wide ecological amplitude
	Other confounding influences affect their status that may complicate the assessment process
Low	Little or no available literature
	Few substantiated or only old vague records of occurrence from the Lake Simcoe watershed
	Extirpated from the Lake Simcoe watershed

Table 2. *Species considered most vulnerable to climate change selected as potential indicators and assessed using the Climate Change Vulnerability Index tool.*

Common name	Scientific name	Grank*	Srank*	COSEWIC*	OMNR*
American ginseng	*Panax quinquefolius*	G3G4	S2	END	END
Eastern prairie fringed-orchid	*Platanthera leucophaea*	G2	S2	END	END
Purple twayblade	*Liparis liliifolia*	G5	S2	END	END
Ram's-head lady's-slipper	*Cypripedium arietinum*	G3	S3	NA*	NA*
Schweinitz's sedge	*Carex schweinitzii*	G3G4	S3	NA*	NA*
Lilypad clubtail	*Arigomphus furcifer*	G5	S3	NA*	NA*
Jefferson salamander	*Ambystoma jeffersonianum*	G4	S2	THR	THR
Western chorus frog (Great Lakes-St. Lawrence—Canadian Shield population)	*Pseudacris triseriata*	G5TNR	S3	THR	NAR
Blanding's turtle	*Emydoidea blandingii*	G4	S3	THR	THR
Milksnake	*Lampropeltis triangulum*	G5	S3	SC	SC
Black tern	*Chlidonias niger*	G4	S3B	NAR	SC
Bobolink	*Dolichonyx oryzivorus*	G5	S4B	THR	THR
Canada warbler	*Wilsonia canadensis*	G5	S4B	THR	SC
Chimney swift	*Chaetura pelagica*	G5	S4B,S4N	THR	THR
Least bittern	*Ixobrychus exilis*	G5	S4B	THR	THR
Yellow rail	*Coturnicops noveboracensis*	G4	S4B	SC	SC
Redside dace	*Clinostomus elongatus*	G3G4	S2	END	END

*For conservation rank definitions refer to glossary of terms.
*NA – these species have not been assessed

Applying the climate change vulnerability index (CCVI) tool

The NatureServe CCVI provides an indication of vulnerability to climate change by the year 2050, a typical cut-off date for projections published in the International Panel on Climate Change reports (e.g., IPCC 2007). The CCVI uses a scoring system that integrates a species' predicted exposure to climate change within the assessment area (in this case the Lake Simcoe watershed), and three sets of factors associated with climate change sensitivity including (1) indirect exposure to climate change; (2) habitat specificity, genetic traits, and dispersal ability; and (3) documented response to climate change (if available).

Exposure to climate change is measured by examining the magnitude of projected temperature, precipitation, and moisture change across the range of species within the assessment area. For the Lake Simcoe study area, moisture deficit data and mean annual ranges of temperature and precipitation for 1951 to 2006 and 2040 to 2069 were taken from Young et al. (2010) and Climate Wizard. Climate Wizard is an online tool that provides climate data from 16 Global Climate Models statistically downscaled to 12 km resolution (http:///www.climatewizard.org). To assess moisture availability, we used the AET:PET Moisture Metric (Hamon 1961), calibrated for the 2040 to 2069 (medium emissions A1B, 16-model ensemble average) generated by NatureServe. The Hamon AET:PET integrates temperature and precipitation through a ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET), with consideration of total daylight hours and saturated vapour pressure. To calculate a score, direct climate exposure was computed as a climate stress index and then used as a weighting factor for the appropriate indirect exposure and sensitivity factors to generate an overall score as illustrated in Figure 3. This score was compared against threshold values to generate a vulnerability index score.

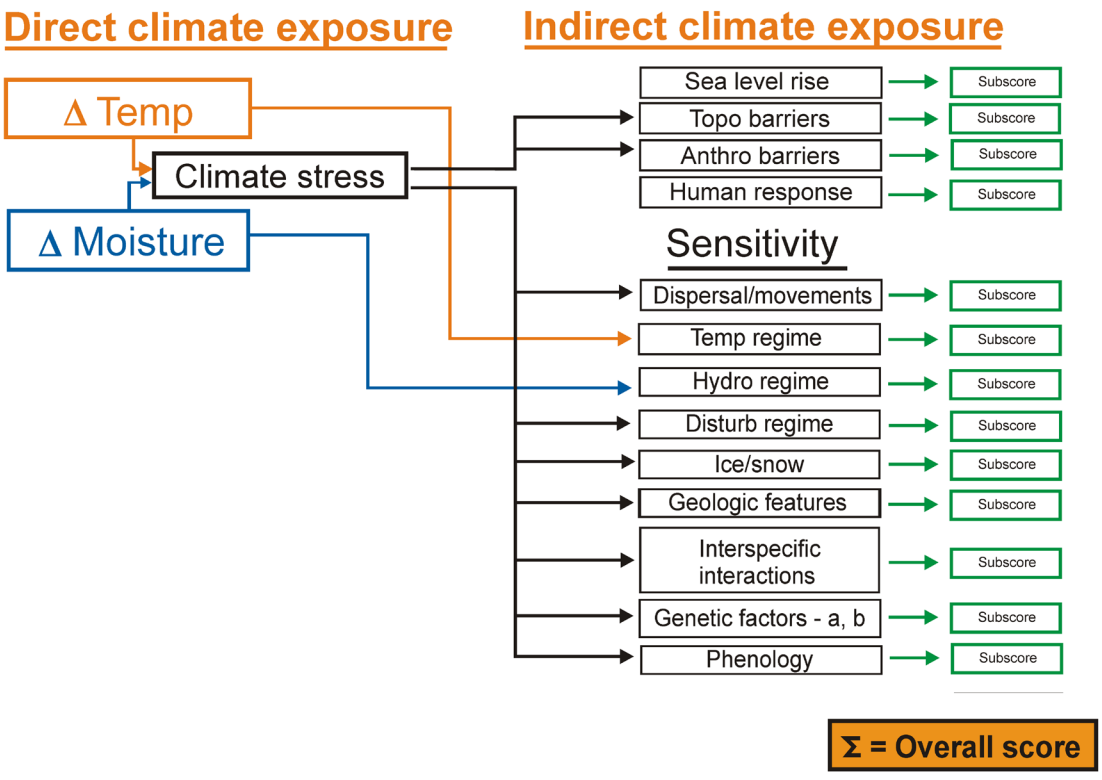

Figure 3. *Direct and indirect climate exposure variables including sensitivity factors used to generate overall vulnerability scores in the climate change vulnerability index (Source: Young et al. 2010).*

A calculated Index score and a measure of confidence was generated by the CCVI tool. Given that some species may not be inherently sensitive to climate change, or are sensitive but not expected to experience significant exposure, the CCVI 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 (described below) provide a relative measure of vulnerability to climate change that, in a rapidly changing climate, helps to separate species with numerous risk factors from those with fewer risk factors or characteristics that may cause their populations to increase.

Index scores based on Young et al. (2010) are defined as follows:

- **Extremely vulnerable:** Abundance and/or range extent within geographical area assessed as extremely likely to substantially decrease or disappear by 2050.
- **Highly vulnerable:** Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.
- **Moderately vulnerable:** Abundance and/or range extent within geographical area assessed likely to decrease by 2050.
- **Not vulnerable/presumed stable:** Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.
- **Not vulnerable/increase likely:** Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050.
- **Insufficient evidence:** Available information about a species' vulnerability is inadequate to calculate an index score.

Results

The results of the climate change vulnerability index assessment were summarized by taxonomic group (see Figure 4). In total, six of 17 species spanning three taxonomic groups were identified as potentially vulnerable to climate change in the Lake Simcoe watershed. Of those six, one fish species was identified as extremely vulnerable, one vascular plant as highly vulnerable, and one amphibian and three vascular plants as moderately vulnerable. The remaining 11 species were not considered vulnerable, with six birds, one invertebrate, and one reptile presumed stable, and one vascular plant likely to increase with projected changes in climate.

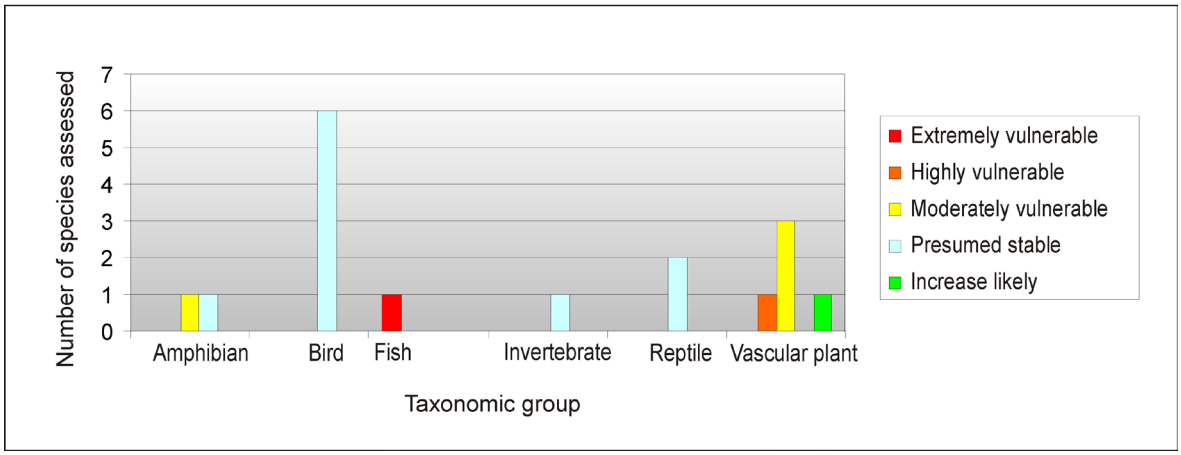

Figure 4. *Results of the climate change vulnerability index assessment for the Lake Simcoe Protection Area Watershed Boundary summarized by major taxonomic group.*

Table 3 outlines the index scores for each vulnerable species. Redside dace (*Clinostomus elongatus)* is likely the most sensitive species, with a score of extremely vulnerable, followed by Schweinitz's sedge (*Carex schweinitzii)* with a score of highly vulnerable. American ginseng (*Panax quinquefolius*), Eastern prairie fringed-orchid (*Platanthera leucophaea)*, ram's-head lady's-slipper (*Cypripedium arietinum)* and Jefferson salamander (*Ambystoma jeffersonianum)* were scored as moderately vulnerable to climate change. All species except ram's-head lady's-slipper are at their northern range limit.

Table 3. *Six species identified as potentially vulnerable to climate change in the Lake Simcoe watershed.*

Indicator	Conservation ranks*	Range	Vulnerability index score
Redside dace	G3G4 S2 END	Northern edge	Extremely Vulnerable
Schweinitz's sedge	G3G4 S3	Northern edge	Highly Vulnerable
American ginseng	G3G4 S2 END	Northern edge	Moderately Vulnerable
Eastern prairie fringed-orchid	G2 S2 END	Northern edge	Moderately Vulnerable
Jefferson salamander	G4 S2 THR	Northern edge	Moderately Vulnerable
Ram's-head lady's-slipper	G3 S3	Centre	Moderately Vulnerable

*For conservation rank definitions refer to glossary of terms.

Discussion

Several bio-physical characteristics were used to assess vulnerability for each of the six indicator species. Typically, these vulnerabilities are associated with the species' specialized life history requirements and dispersal capabilities, the barriers to dispersal in the watershed, the degree of habitat specialization, or the physiological relationship of the species with temperature and moisture. Key vulnerabilities for each species are summarized below, and those that may be affected by changes in climate are identified.

Redside dace

- **Barriers**: almost completely surround the current distribution of the species such that distributional shifts are unlikely. In other words, there is no suitable habitat physically connecting populations in the Lake Simcoe watershed with those in other potentially suitable sites.
- **Thermal niche**: requires cold, clear water streams; warming and increases in turbidity may affect survival.
- **Dietary versatility**: specialized diet and foraging strategy, which involves leaping out of the water to catch terrestrial insects, mostly flies; requires clear water; increased turbidity may limit foraging success.

Schweinitz's sedge

- **Barriers**: study area bordered by Lake Simcoe, which forms a natural barrier.
- **Thermal niche**: requires cool, stream edges, springheads, and seeps; warming may affect survival by altering these habitats.
- **Hydrological niche**: specialized habitat requirements relating to areas of constant seepage; drying may affect distribution/occurrence.
- **Restriction to uncommon geological features**: restricted to calcareous substrates.

American ginseng

- **Dispersal**: limited ability to disperse through unsuitable habitat.
- **Disturbance**: increased vulnerability to catastrophic/stochastic environmental events such as wind or ice storms.

Eastern prairie fringed-orchid

- **Hydrological niche**: completely dependent on specialized wetland habitat that is mineral rich, often fed by groundwater, and maintained via seasonal flooding; the latter two physical conditions could be affected by climate change.
- **Pollinator specificity**: dependent on a few species for pollination such that any negative effects of climate change on these would also negatively affect their reproductive output/success.
- **Interspecific interaction**: requires a specialized fungal symbiont for seedling establishment.

Jefferson salamander

- **Barriers**: natural and anthropogenic barriers border the current distribution (i.e., major 400-series highway, urban centres, Lake Simcoe) such that climate change-caused distributional shifts are likely to be impaired in the assessment area.
- **Hydrological niche**: requires specific vernal pool habitat for reproduction that may be affected if climate change influences hydrology.

Ram's-head lady's-slipper

- **Thermal niche**: almost completely restricted to cool environments that may be significantly reduced or lost with climate change.
- **Hydrological niche**: somewhat dependant on specific wetland habitat.
- **Pollinator specificity**: requires specific pollinators such that any negative effects on these from climate change would negatively affect reproductive output/success.
- **Interspecific interaction**: requires specialized fungal symbionts for seedling establishment.

A degree of uncertainty is associated with climate change models and scenarios, and because the tool does not account for this uncertainty, these results should be used as projections only.

Recommendations

Based on the results from the CCVI tool, certain provincially rare species in the Lake Simcoe watershed are likely vulnerable to climate change to varying degrees and require consideration in conservation planning to ensure populations are sustained in the long-term. The potential effects of climate change on these species should be integrated with and weighed against other known stressors and threats from within the watershed. Based on the vulnerabilities of each of the six species identified, options should be developed that will benefit multiple species to maximize efficiency where vulnerabilities overlap.

None of the six species are being monitored quantitatively such that climate change effects could be detected. If these species were actively monitored throughout the Lake Simcoe watershed, practitioners and decisionmakers would be in a better position to assess overall population status (i.e., decline, increase, or stable), and to detect the expansion and contraction of each species across the study area. While detailed location data on occurrences of these species are available, the data are mostly based on incidental observations rather than thorough, systematic surveys that encompass the entire study area. This limits our ability to assess their overall status because we cannot be completely confident that most or all occurrences in the study area have been detected. Future adaptive strategies should include conducting more complete inventories and mapping all known occurrences of each species to provide a quantitative baseline for future monitoring in the watershed. Consideration could also be given to expanding these surveys to other suitable habitat.

References

[COSEWIC] Committee on the Status of Endangered Wildlife in Canada. 2010. COSEWIC's Assessment Process and Criteria. Approved by COSEWIC in April 2010. (www.cosewic.gc.ca/pdf/assessment_process_e.pdf*; accessed December 2010)*

Government of Ontario. 2009. Lake Simcoe Protection Plan. Toronto, Ontario. 91p. (http://eee.ene.gov.on.ca/publications/6932e01.pdf).

Government of Ontario. 2011. Climate Ready: Ontario's Adaptation Strategy and Action Plan, 2011-2014. Government of Ontario, Toronto, Ontario, Canada 120p. (http://www.ene.gov.on.ca/environment/en/blog/STDPROD_085442.html).

Hamon, W.R. 1961. Estimating potential evapotranspiration. J. Hydraul. Div., Proc. Am. Soc. Civil Engineer. 87: 107-120.

[IPCC] Intergovernmental Panel on Climate Change. 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson, eds., Cambridge University Press, Cambridge, UK. 976 pp. (http://www.ipcc.ch/ipccreports/ar4-wg2.htm; accessed July 2012)

[MNR] Ministry of Natural Resources. 2011. Sustainability in a Changing Climate: A Strategy for the Ontario Ministry of Natural Resources, 2011-2014. Ministry of Natural Resources, Peterborough, Ontario. 25p.

[MOE] Ministry of Environment, Ministry of Natural Resources, Lake Simcoe Region Conservation Authority, and DMTI Spatial Inc. 2009. Lake Simcoe Protection Plan. Toronto, ON. 91p. (http://www.ene.gov.on.ca/environment/en/resources/STD01_076301.html; accessed July 2012)

NatureServe. 2010. NatureServe Status and Ranking Definitions. (http://www.natureserve.org/explorer/ranking.htm; accessed December 2010)

[NHIC] Natural Heritage Information Centre. 2010. Element occurrence database. Ont. Min. Nat Resour., Natural Heritage Info. Cent., Peterborough, ON. Electronic database.

Statutes of Ontario. 2007. Endangered Species Act. S.O. 2007, Chapter 6 (http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_07e06_e.htm; accessed December 2010)

Young, B., E. 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. 48p.

Glossary of Terms

COSEWIC (Committee on the Status of Endangered Wildlife in Canada) - A committee of experts who assess and designate wildlife species that are in danger of disappearing from Canada (COSEWIC 2010).

EO (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: it is a location important to the conservation of the species or community. For a species, an EO 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 EOs. For an ecological community, an EO may be the area containing a patch of that community type (NatureServe 2010).

END (endangered) - A native species facing imminent extinction or extirpation (COSEWIC 2010).

GIS (geographic information system) - Computer software that allows spatial data to be viewed, manipulated, and printed.

GRANK (global rank) - Global ranks are assigned by a consensus of the network of Conservation Data Centres, scientific experts, and The Nature Conservancy to designate a rarity rank based on the range-wide status of a species, subspecies, or variety (NatureServe 2010).

G1 (**extremely rare) -** Usually five or fewer occurrences in the overall range or very few remaining individuals; or because of some factor(s) making it especially vulnerable to extinction (NatureServe 2010).

G2 (**very rare) -** Usually between five and 20 occurrences in the overall range or with many individuals in fewer occurrences; or because of some factor(s) making it vulnerable to extinction (NatureServe 2010).

G3 (**rare to uncommon**) - Usually between 20 and 100 occurrences; may have fewer occurrences, but with many individuals in some populations; may be susceptible to large-scale disturbances (NatureServe 2010).

G4 (apparently secure) - Uncommon but not rare; some cause for long-term concern due to declines or other factors (NatureServe 2010).

G5 (secure) – Common; widespread and abundant (NatureServe 2010).

GNR (not ranked) - Rank not yet assessed (NatureServe 2010).

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 (NatureServe 2010).

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. A T subrank cannot imply the subspecies or variety is more abundant than the species. For example, a G1T2 subrank should not occur. A vertebrate animal population, (e.g., listed under the U.S. *Endangered Species Act* or assigned candidate status) may be tracked as an infraspecific taxon and given a T-rank; in such cases a Q is used after the T-rank to denote the taxon's informal taxonomic status (NatureServe 2010).

NAR (not at risk) – A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances (COSEWIC 2010).

SAR (species at risk) - An extirpated, endangered, or threatened species, or a species of special concern (COSEWIC 2010).

SC (special concern) - A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats (COSEWIC 2010).

Species - The lowest principal unit of biological classification formally recognized as a group of organisms distinct from other groups. In sexually producing organisms, "species" is more narrowly characterized as a group of organisms that in natural conditions freely interbreed with members of the same group but not with members of other groups.

SRANK (provincial rank) - Provincial (or sub-national) ranks used by the Natural Heritage Information Centre (NHIC) to set protection priorities for rare species and natural communities. These ranks are not legal designations. Provincial ranks are assigned in a manner similar to that described for global ranks, but consider only those factors within the political boundaries of Ontario. By comparing the global and provincial ranks, the status, rarity, and urgency of conservation needs can be determined. The NHIC continually evaluates provincial rankings and produces updated lists at least annually (NatureServe 2010).

SH (possibly extirpated) - Species or community occurred historically in the province, and has the possibility to be rediscovered. Its presence may not have been verified in the past 20 to 40 years. A species or community could become SH without the time delay if the only known occurrences in the province were destroyed or if it had been extensively and unsuccessfully looked for. The SH rank is 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 (NatureServe 2010).

S1 (critically imperilled) - Critically imperilled in the province because of extreme rarity (often five or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation (NatureServe 2010).

S2 (imperilled) - Imperilled in the province because of rarity 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 nation or state/province (NatureServe 2010).

S3 (vulnerable) - Vulnerable in the province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation (NatureServe 2010).

S4 (apparently secure) - Uncommon but not rare in the province; some cause for long-term concern due to declines or other factors (NatureServe 2010).

S5 (secure) - Common, widespread, and abundant in the province (NatureServe 2010).

S#S# (range rank) - A numeric range rank (e.g., S2S3, S1S3) used to indicate the range of uncertainty about the exact status of a taxon or ecosystem type (NatureServe 2010).

S#B (breeding) - Conservation status refers to the breeding population of the species in the province (NatureServe 2010).

S#N (nonbreeding) - Conservation status refers to the non-breeding population of the species in the province (NatureServe 2010).

S#? (inexact numeric rank) - Denotes unknown numeric rank (NatureServe 2010).

THR (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 2010).

Appendix

Priority rankings for assessing vulnerability of provincially rare species that occur in the Lake Simcoe watershed.

Provincially rare species known to occur within the Lake Simcoe watershed ranked by their priority (1 to 3) to be assessed using the NatureServe climate change vulnerability index and the supporting rationale for the ranking. Also included in the table are the Global Conservation Status Rank (Grank), Sub-national (in this case Ontario) Conservation Status Rank (Srank), and the relevant status as assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and by the Ontario Ministry of Natural Resources (OMNR) under Ontario's *Endangered Species Act* (Statutes of Ontario 2007). SAR = species-at-risk.

1	High priority species with OMNR/COSEWIC status; globally and/or provincially rare/at northern or southern range limit/likely vulnerable to climate change based on habitat or life history requirements/good amount of literature available/recent, substantiated records of occurrence
2	Medium priority species that are provincially rare/widespread/lack information pertaining to Ontario/have wide ecological amplitudes/ possess other confounding influences affecting their status that may complicate the assessment process
3	Low priority species with little available literature/few substantiated or old vague records, or extirpated from the watershed

Rank	Scientific name	Common name	Rationale for rankings	Grank*	Srank*	COSEWIC*	OMNR*
1	Ambystoma jeffersonianum	Jefferson salamander	SAR; northern range limit; threats related to shorter availability of breeding ponds; sufficient biological/ ecological literature available (including Jefferson x blue-spotted salamander occurrences)	G4	S2	THR	THR
1	*Arigomphus furcifer*	Lilypad clubtail	provincially rare; distribution in Ontario largely confined to the southern edge of the Canadian Shield	G5	S3	NA*	NA*
1	*Carex schweinitzii*	Schweinitz's sedge	globally rare to uncommon; narrow ecological amplitude – dependant on calcareous, perennially wet, seepy habitats along spring-fed rivers and brooks, in mixed or coniferous cover; likely susceptible to hydrological and temperature changes	G3G4	S3	NA*	NA*
1	*Chaetura pelagica*	Chimney swift	Newly added SAR; has declined dramatically in Ontario with some of the greatest declines occurring in the Lake Simcoe region; sufficient biological/ ecological information available	G5	S4B,S4N	THR	THR
1	*Chlidonias niger*	Black tern	SAR; declining; distribution in Ontario largely confined to the southern edge of the Canadian Shield	G4	S3B	NAR	SC
1	*Clinostomus elongatus*	Redside dace	SAR; globally rare and declining; prefers clear cool streams	G3G4	S2	END	END
1	*Coturnicops noveboracensis*	Yellow rail	SAR; most Ontario populations occur in the Hudson Bay Lowland and Rainy River District; 90% of the species' breeding range occurs in Canada; rare and very local in the south but is known to breed in the Lake Simcoe watershed	G4	S4B	SC	SC
1	*Cypripedium arietinum*	Ram's-head lady's-slipper	globally rare (G3); usually found in areas with cool microclimates (populations are often confined to northern exposures or cold air channels); potentially declining; sensitive to moisture/hydrological changes	G3	S3	NA*	NA*

Rank	Scientific name	Common name	Rationale for rankings	Grank*	Srank*	COSEWIC*	OMNR*
1	*Dolichonyx oryzivorus*	Bobolink	newly added SAR but still a fairly common breeding species in the Lake Simcoe watershed; sufficient biological/ecological information available	G5	S4B	THR	THR
1	*Emydoidea blandingii*	Blanding's turtle	SAR; high proportion of global range in Ontario; long generation time (exceeding 40 years) which limits its ability to adapt genetically to short-term environmental changes; lots of literature	G4	S3	THR	THR
1	*Ixobrychus exilis*	Least bittern	SAR; rare and local breeder; may be decreasing in abundance; in Ontario, mostly found south of the Canadian Shield	G5	S4B	THR	THR
1	*Lampropeltis triangulum*	Milksnake	SAR; found in anthropogenic landscapes and susceptible to the effects of human encroachment/ habitat loss; persecuted species	G5	S3	SC	SC
1	*Liparis liliifolia*	Purple twayblade	SAR; northern range limit but apparently expanding; wide ecological amplitude	G5	S2	END	END
1	*Panax quinquefolius*	American ginseng	SAR; declining; fragmented populations likely highly vulnerable to environmental stochasticity; poor dispersal ability; lots of literature	G3G4	S2	END	END
1	*Platanthera leucophaea*	Eastern prairie fringed-orchid	SAR; globally rare (G2G3); narrow ecological amplitude; northern range limit; sensitive to moisture/hydrological changes; lots of literature	G2G3	S2	END	END
1	*Pseudacris triseriata*	Western chorus frog (Great Lakes-St. Lawrence—Canadian Shield Population)	federal SAR; low dispersal ability and relatively high site-fidelity; limited ability to cope with habitat fragmentation and reduced habitat quality	G5TNR	S3	THR	NAR
1	*Wilsonia canadensis*	Canada warbler	newly added SAR but still quite common and widespread; 80% of the breeding range occurs in Canada with the greatest concentration in the southern Canadian Shield region; prefers damp wooded habitat	G5	S4B	THR	SC
2	*Caprimulgus vociferus*	Whip-poor-will	newly added SAR; like many aerial insectivores, has declined significantly in Ontario; declines may be related to natural forest succession or use of insecticides	G5	S4B	THR	THR
2	*Chelydra serptentina*	Snapping turtle	widespread and still numerous; concerns over declining populations, human exploitation (legal and illegal harvest), and road mortality	G5	S3	SC	SC
2	*Chordeiles minor*	Common nighthawk	Newly added SAR; like many aerial insectivores, has declined significantly in Ontario; declines may be related to natural forest succession or use of insecticides	G5	S4B	THR	SC
2	*Dendroica cerulea*	Cerulean warbler	SAR; declining; at the northern edge of its range	G4	S3B	SC	SC
2	*Graptemys geographica*	Northern map turtle	relatively widespread; lower priority SAR	G5	S3	SC	SC

Rank	Scientific name	Common name	Rationale for rankings	Grank*	Srank*	COSEWIC*	OMNR*
2	*Hydroprogne caspia*	Caspian tern	designated "Not at Risk" by COSSARO and COSEWIC; mostly nests on islands in the Great Lakes although does nest on larger inland lakes including Lake Simcoe	G5	S3B	NAR	NAR
2	*Juglans cinerea*	Butternut	widespread but declining; may be hard to factor the effects of climate change given species susceptibility to butternut canker (*Sirococcus clavigignenti-juglandacearum*) disease and that climate varies greatly within its range	G4	S3?	END	END
2	*Juncus secundus*	One-sided rush	relatively widespread in southern Ontario; alvars and rock barrens	G5?	S3	NA*	NA*
2	*Lanius ludovicianus*	Loggerhead shrike	one of Ontario's most endangered species; has declined dramatically since 1966 for reasons not fully understood but may be related in part to natural succession; not considered a good candidate for this analysis given the uncertainty around reason for declines	G4	S2B	END	END
2	*Melanerpes erythrocephalus*	Red-headed woodpecker	has declined in Ontario, but declines are largely associated with a decrease in available nesting sites (old snags) and the spread of beech bark disease (*Nectria coccinea* var. *faginata*) and the resultant decline in American beech (*Fagus grandifolia*), an important forage species	G5	S4B	THR	SC
2	*Myotis septentrionalis*	Northern long-eared bat	currently not a SAR but with concerns over white nose syndrome may soon become one	G4	S3?	NA*	NA*
2	*Sporobolus heterolepis*	Prairie dropseed	widespread; known from northwestern and southern Ontario; prairies, alvars, rocky areas	G5	S3	NA*	NA*
2	*Thamnophis sauritus*	Eastern ribbonsnake	lack of information about Ontario populations; shoreline/wetland habitat degraded; may be sensitive to amphibian decline	G5	S3	SC	SC
2	*Trichophorum clintonii*	Clinton's clubrush	widespread but generally locally rare; fairly wide ecological amplitude; limited published literature	G4	S2S3	NA*	NA*
3	*Aeshna clepsydra*	Mottled darner	lack of biological/ecological information; historical records only	G4	S3	NA*	NA*
3	*Aeshna verticalis*	Green-striped darner	lack of biological/ecological information; historical records only	G5	S3	NA*	NA*
3	*Ammodramus henslowii*	Henslow's sparrow	number of Henslow's sparrows in Ontario is extremely low, and its distribution is scattered and somewhat unpredictable; breeding has not been confirmed within the past 20 years; declines in Ontario are likely a result of changes in agricultural land use; may not be a good candidate for this analysis	G4	SHB	END	END
3	*Arigomphus cornutus*	Horned clubtail	very few records in the watershed	G4	S3	NA*	NA*
3	*Arigomphus villosipes*	Unicorn clubtail	historic; no recent records in the watershed	G5	S2S3	NA*	NA*
3	*Asio flammeus*	Short-eared owl	largely a nomadic species therefore effects of climate change will likely be difficult to ascertain	G5	S2N,S4B	SC	SC
3	*Asterocampa celtis*	Hackberry emperor	actual location falls outside Lake Simcoe watershed (accuracy buffer just inside Lake Simcoe watershed boundary)	G5	S2	NA*	NA*

Rank	Scientific name	Common name	Rationale for rankings	Grank*	Srank*	COSEWIC*	OMNR*
3	*Bartonia virginica*	Yellow bartonia	actual location falls outside Lake Simcoe watershed (accuracy buffer just inside Lake Simcoe watershed boundary)	G5	S2	NA*	NA*
3	Brachythecium calcareum		lack of biological/ecological information	G3G4	S2	NA*	NA*
3	*Chenopodium foggii*	Fogg's goosefoot	questionable record; difficulty with identifications	G2G3	S2	NA*	NA*
3	*Crataegus brainerdii*	Brainerd's hawthorn	vague, historic record; no recent information; lack of biological/ecological information	G5	S2	NA*	NA*
3	Cyperus houghtonii	Houghton's flatsedge	can be weedy; lack of published literature	G4?	S3	NA*	NA*
3	*Dichanthelium ovale ssp. praecocius*	White-haired panic grass	lack of biological/ecological information	G5T5?	S3	NA*	NA*
3	*Enallagma aspersum*	Azure bluet	lack of biological/ecological information	G5	S3	NA*	NA*
3	*Glyptemys insculpta*	Wood turtle	1 dead on road specimen from the study area at the Royal Ontario Museum; 1 other historic record; few substantiated records; data sensitivity issues	G4	S2	THR	END
3	*Gomphus graslinellus*	Pronghorn clubtail	only a single historic record	G5	S3	NA*	NA*
3	*Heterodon platirhinos*	Eastern hog-nosed snake	vague record falls outside Lake Simcoe watershed (accuracy buffer just inside Lake Simcoe watershed boundary); no recent records from Lake Simcoe watershed	G5	S3	THR	THR
3	*Houstonia caerulea*	Bluets	Historic; no recent records in Ontario	G5	SH	NA*	NA*
3	*Icteria virens*	Yellow-breasted chat	no confirmed breeding in the Lake Simcoe watershed – mostly a Carolinian species.	G5	S2B	SC	SC
3	*Lestes eurinus*	Amber-winged spreadwing	lack of biological/ecological information	G4	S3	NA*	NA*
3	*Moxostoma valenciennesi*	Greater redhorse	actual location falls outside Lake Simcoe watershed (accuracy buffer just inside Lake Simcoe watershed boundary)	G4	S3	NA*	NA*
3	*Poa saltuensis ssp. languida*	Weak blue grass	vague data; lack of biological/ecological information	G5T3T4Q	S3	NA*	NA*
3	Pterospora andromedea	Woodland pinedrops	actual location falls outside Lake Simcoe watershed (accuracy buffer just inside Lake Simcoe watershed boundary)	G5	S2	NA*	NA*
3	*Rallus elegans*	King rail	likely extirpated from the watershed	G4	S2B	END	END
3	*Sistrurus catenatus*	Massasauga	vague, historic record; not part of accepted range; no recent sightings	G3G4	S3	THR	THR
3	*Somatochlora ensigera*	Plains emerald	only a single historic record	G4	S1	NA*	NA*
3	*Somatochlora forcipata*	Forcipate emerald	only a single historic record	G5	S3	NA*	NA*
3	*Somatochlora tenebrosa*	Clamp-tipped emerald	only historic records exist	G5	S2S3	NA*	NA*
3	*Stylurus spiniceps*	Arrow clubtail	only a single historic record	G5	S2	NA*	NA*
3	*Vertigo elatior*	Tapered vertigo	lack of biological / ecological information	G5	S2S3	NA*	NA*
3	*Zizania aquatica*	Indian wild rice	some populations in Ontario likely introduced	G5	S3	NA*	NA*

*For conservation rank definitions refer to glossary of terms.

*NA these species have not been assessed

Climate Change Research Publication Series

Reports

CCRR-01 Wotton, M., K. Logan and R. McAlpine. 2005. Climate Change and the Future Fire Environment in Ontario: Fire Occurrence and Fire Management Impacts in Ontario Under a Changing Climate.

CCRR-02 Boivin, J., J.-N. Candau, J. Chen, S. Colombo and M. Ter-Mikaelian. 2005. The Ontario Ministry of Natural Resources Large-Scale Forest Carbon Project: A Summary.

CCRR-03 Colombo, S.J., W.C. Parker, N. Luckai, Q. Dang and T. Cai. 2005. The Effects of Forest Management on Carbon Storage in Ontario's Forests.

CCRR-04 Hunt, L.M. and J. Moore. 2006. The Potential Impacts of Climate Change on Recreational Fishing in Northern Ontario.

CCRR-05 Colombo, S.J., D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. Climate Change Projections for Ontario: Practical Information for Policymakers and Planners.

CCRR-06 Lemieux, C.J., D.J. Scott, P.A. Gray and R.G. Davis. 2007. Climate Change and Ontario's Provincial Parks: Towards an Adaptation Strategy.

CCRR-07 Carter, T., W. Gunter, M. Lazorek and R. Craig. 2007. Geological Sequestration of Carbon Dioxide: A Technology Review and Analysis of Opportunities in Ontario.

CCRR-08 Browne, S.A. and L.M Hunt. 2007. Climate Change and Nature-based Tourism, Outdoor Recreation, and Forestry in Ontario: Potential Effects and Adaptation Strategies.

CCRR-09 Varrin, R. J. Bowman and P.A. Gray. 2007. The Known and Potential Effects of Climate Change on Biodiversity in Ontario's Terrestrial Ecosystems: Case Studies and Recommendations for Adaptation.

CCRR-11 Dove-Thompson, D. C. Lewis, P.A. Gray, C. Chu and W. Dunlop. 2011. A Summary of the Effects of Climate Change on Ontario's Aquatic Ecosystems.

CCRR-12 Colombo, S.J. 2008. Ontario's Forests and Forestry in a Changing Climate.

CCRR-13 Candau, J.-N. and R. Fleming. 2008. Forecasting the Response to Climate Change of the Major Natural Biotic Disturbance Regime in Ontario's Forests: The Spruce Budworm.

CCRR-14 Minns, C.K., B.J. Shuter and J.L. McDermid. 2009. Regional Projections of Climate Change Effects on Ontario Lake Trout (*Salvelinus namaycush*) Populations.

CCRR-15 Subedi, N., M. Sharma, and J. Parton. 2009. An Evaluation of Site Index Models for Young Black Spruce and Jack Pine Plantations in a Changing Climate.

CCRR-16 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.

CCRR-17 Hasnain, S.S., C.K. Minns and B.J. Shuter. 2010. Key Ecological Temperature Metrics for Canadian Freshwater Fishes.

CCRR-18 Scoular, M., R. Suffling, D. Matthews, M. Gluck and P. Elkie. 2010. Comparing Various Approaches for Estimating Fire Frequency: The Case of Quetico Provincial Park.

CCRR-19 Eskelin, N., W. C. Parker, S.J. Colombo and P. Lu. 2011. Assessing Assisted Migration as a Climate Change Adaptation Strategy for Ontario's Forests: Project Overview and Bibliography.

CCRR-20 Stocks, B.J. and P.C. Ward. 2011. Climate Change, Carbon Sequestration, and Forest Fire Protection in the Canadian Boreal Zone.

CCRR-21 Chu, C. 2011. Potential Effects of Climate Change and Adaptive Strategies for Lake Simcoe and the Wetlands and Streams within the Watershed.

CCRR-22 Walpole, A and J. Bowman. 2011. Wildlife Vulnerability to Climate Change: An Assessment for the Lake Simcoe Watershed.

CCRR-23 Evers, A.K., A.M. Gordon, P.A. Gray and W.I. Dunlop. 2012. Implications of a Potential Range Expansion of Invasive Earthworms in Ontario's Forested Ecosystems: A Preliminary Vulnerability Analysis.

CCRR-24 Lalonde, R., J. Gleeson, P.A. Gray, A. Douglas, C. Blakemore and L. Ferguson. 2012. Climate Change Vulnerability Assessment and Adaptation Options for Ontario's Clay Belt – A Case Study.

CCRR-25 Bowman, J. and C. Sadowski. 2012. Vulnerability of Furbearers in the Clay Belt to Climate Change.

CCRR-26 Rempel, R.S. 2012. Effects of Climate Change on Moose Populations: A Vulnerability Analysis for the Clay Belt Ecodistrict (3E-1) in Northeastern Ontario.

CCRR-27 Minns, C.K., B.J. Shuter and S. Fung. 2012. Regional Projections of Climate Change Effects on Ice Cover and Open-Water Duration for Ontario Lakes

CCRR-28 Lemieux, C.J., P. A. Gray, D.J. Scott, D.W. McKenney and S. MacFarlane. 2012. Climate Change and the Lake Simcoe Watershed: A Vulnerability Assessment of Natural Heritage Areas and Nature-Based Tourism.

CCRR-29 Hunt, L.M. and B. Kolman. 2012. Selected Social Implications of Climate Change for Ontario's Ecodistrict 3E-1 (The Clay Belt).

CCRR-30 Chu, C. and F. Fischer. 2012. Climate Change Vulnerability Assessment for Aquatic Ecosystems in the Clay Belt Ecodistrict (3E-1) of Northeastern Ontario.

Notes

CCRN-01 Warner, B.G., J.C. Davies, A. Jano, R. Aravena, and E. Dowsett. 2003. Carbon Storage in Ontario's Wetlands.

CCRN-02 Colombo, S.J. 2006. How OMNR Staff Perceive Risks Related to Climate Change and Forests.

CCRN-03 Obbard, M.E., M.R.L. Cattet, T. Moody, L.R. Walton, D. Potter, J. Inglis, and C. Chenier. 2006. Temporal Trends in the Body Condition of Southern Hudson Bay Polar Bears.

CCRN-04 Jackson, B. 2007. Potential Effects of Climate Change on Lake Trout in Atikokan Area.

CCRN-05 Bird, N.D. and E. Boysen. 2006. The Carbon Sequestration Potential from Afforestation in Ontario.

CCRN-06 Colombo, S.J., J. Chen and M.T. Ter-Mikaelian. 2006. Carbon Storage in Ontario's Forests, 2000-2100.

CCRN-07 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.

CCRN-08 Colombo, S.J., B. Boysen, K. Brosemer, A. Foley and A. Obenchain. 2008. Managing Tree Seed in an Uncertain Climate: Conference Summary.

CCRN-09 Gleeson, J., G. Nielsen and W.C. Parker. 2009. Carbon Offsets from Afforestation and the Potential for Landowner Participation in Ontario.

CCRN-10 Parker, W.C., G. Nielsen, J. Gleeson and R. Keen. 2009. Forecasting Carbon Storage and Carbon Dioxide Offsets for Southern Ontario Afforestation Projects: The 50 Million Tree Planting Program.

CCRN-11 Gleeson, J. and D. La Croix-McDougall. 2009. MNR's Carbon Footprint: An Assessment for Three Business Areas.

52709
(0.2k P.R., 12 10 31)
ISBN 978-1-4606-0577-6 (print)
ISBN 978-1-4606-0578-3 (pdf)