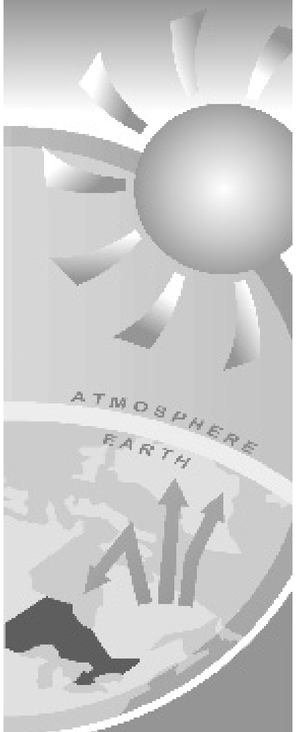
Ministry of Natural Resources

28

CLIMATE CHANGE RESEARCH REPORT

CCRR-28



Responding to Climate Change Through Partnership

Climate Change and the Lake Simcoe Watershed:

A Vulnerability Assessment of Natural Heritage Areas and Nature-based Tourism

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.

Climate Change and the Lake Simcoe Watershed:

A Vulnerability Assessment of Natural Heritage Areas and Nature-based Tourism

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Summary

Climate change presents several challenges to planners and those responsible for managing natural heritage areas and providing nature-based recreational opportunities. We explore the vulnerability of natural heritage areas and nature-based recreation to climate change in the Lake Simcoe watershed in two ways. First, we examine the vulnerability of natural heritage areas to climate change using habitat projections for selected tree species. Second, we explore the vulnerability of nature-based tourism to climate change using ice fishing, alpine skiing, Nordic skiing, and snowmobiling season lengths and provincial park visitation patterns.

Climate model projections indicate potential for significant change in ecosystem function in natural heritage areas and subsequent effects on nature-based tourism, resulting in many possible management implications. For example, climate conditions that provide habitat for boreal species such as black spruce (*Picea mariana*) are projected to disappear while those ideal for more southerly species such as willow oak (*Quercus phellos*) are projected to develop in the Lake Simcoe area. Projections from climate models point towards substantial reductions in the length of ice fishing, alpine and Nordic skiing, and snowmobiling seasons. As temperatures warm, interest in visiting natural heritage areas may increase, especially during the spring and fall shoulder seasons and the peak summer period. For example, annual visits to Sibbald Point Provincial Park are projected to increase 10% by the 2020s, 19 to 28% by mid-century (2050s), and 24 to 48% by the 2080s. Responding to the threats and opportunities resulting from climate change will require commitment, collaboration, and innovation characteristic of an adaptive approach to management.

Résumé

Le changement climatique et le bassin hydrographique du lac Simcoe : Évaluation de la vulnérabilité des zones de patrimoine naturel et de tourisme axé sur la nature

Le changement climatique représente plusieurs défis pour les planificateurs et les responsables de la gestion des zones de patrimoine naturel et de l'offre de possibilités récréatives axées sur la nature. Nous étudions de deux façons la vulnérabilité au changement climatique des zones de patrimoine naturel et de loisirs axés sur la nature du bassin hydrographique du lac Simcoe, dans le Sud de l'Ontario, D'abord, nous évaluons la vulnérabilité au changement climatique des zones de patrimoine naturel à l'aide de projections d'habitat de trois espèces choisies. Deuxièmement, nous évaluons la vulnérabilité au changement climatique des zones de tourisme axé sur la nature en examinant la durée des saisons de pêche sur la glace, de ski alpin, de ski nordique et de motoneige ainsi que les habitudes de visite des parcs provinciaux.

Les prévisions quant à un modèle climatique indiquent la possibilité de changements importants dans la fonction de l'écosystème dans les zones de patrimoine naturel, ainsi que des effets ultérieurs sur le tourisme axé sur la nature, qui pourraient entraîner de nombreuses répercussions liées à la gestion. Par exemple, on prévoit que les conditions climatiques qui fournissent un habitat aux espèces boréales comme l'épinette noire (picea mariana) disparaitront tandis qu'on prévoit que celles qui sont idéales pour les espèces plus au sud comme le chêne à feuille de saule (quercus phellos) devraient se développer dans la région du lac Simcoe. Les prévisions tirées des modèles climatiques pointent vers d'importantes réductions de la longueur des saisons de pêche sur la glace, de ski alpin et nordique et de motoneige. À mesure que les températures se réchauffent, l'intérêt pour visiter les zones de patrimoine naturel pourrait augmenter, tout particulièrement durant les saisons intermédiaires du printemps et de l'automne et durant la haute saison estivale. Dans le parc provincial Sibbald Point, par exemple, on prévoit une hausse de 10 % des visites annuelles d'ici les années 2020, de 19 % à 28 % d'ici le milieu du siècle (2050) et de 24 % à 48 % d'ici les années 2080. Pour répondre aux menaces et aux possibilités résultant du changement climatique, il faudra de l'engagement, de la collaboration et de l'innovation dans le cadre d'une approche adaptative à la gestion.

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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 the Ontario Ministry of Natural Resources 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

1.0 Introduction

The Lake Simcoe watershed encompasses a wealth of natural heritage assets including Lake Simcoe and other lakes, streams and rivers, significant woodlands and valleylands, numerous wetlands, and many species of plants and animals in a variety of aquatic and terrestrial habitats. These natural assets attract hundreds of thousands of visitors every year and generate millions of dollars for the local and provincial economies. Given the anticipated growth of cities, such as Barrie and Orillia, in the watershed and its proximity to the Greater Toronto Area, demand for recreational opportunities and access to provincial parks, conservation areas, and other natural heritage areas is expected to grow.

Climate change presents several challenges to planners and those responsible for managing natural heritage areas and providing nature-based tourism opportunities. For example, warmer temperatures and altered precipitation patterns could reduce, eliminate, or increase opportunities for recreational activities such as skiing, snowmobiling, ice fishing, hiking, boating, and swimming, currently enjoyed by those living in and visiting the Lake Simcoe watershed. In addition, increased frequency and intensity of extreme weather events such as flooding, drought, and windstorms as well as wider distribution and increased abundance of invasive species could affect human health and safety and the condition of natural heritage areas throughout the watershed.

Tourism is a dynamic and competitive industry, requiring constant adaptation to meet changing customer needs, desires, and satisfaction levels and to ensure human safety. Throughout the 21st century, climate change is expected to compound these challenges. In light of the potential for significant effects of projected changes in climate on natural heritage areas and recreational opportunities, we explore:

- the vulnerability of natural heritage areas to climate change using the projected presence or absence of tree habitat as an indicator of change
- the vulnerability of nature-based tourism and recreation to climate change using five indicators of change: ice fishing, alpine skiing, Nordic skiing, and snowmobiling season length, and provincial park visitation patterns

2.0 Natural Heritage Areas and Nature-based Tourism in the Lake Simcoe Watershed

The Lake Simcoe watershed encompasses about 330,300 ha. Principal land uses include agriculture (about 48% of the watershed area) and transportation and urban infrastructure (about 18% of the watershed area). While 35% of the watershed is under natural cover, this cover is significantly fragmented (Government of Ontario 2009). Natural heritage areas (e.g., provincial parks, areas of natural and scientific interest, and conservation areas) encompass about 6.8% of the watershed and are located on provincial, municipal, and private land (Figure 1; Table 1). In Ontario, the phrase *natural heritage area* refers to a group of land designations that collectively contribute to maintaining and enhancing Ontario’s biodiversity. These areas are assigned boundaries, protected through regulation and/or policy, and are afforded special consideration with respect to permitted human uses (Gray et al. 2009).

Nature-based tourism opportunities in the watershed are enjoyed by many residents and visitors. For example, many of the 6.2 million people who visited Simcoe County in 2008 (an area located in the western and northern part of the Lake Simcoe Watershed) participated in nature-based activities.Total spending by visitors pursuing recreational activities exceeded $34 million and generated a total economic impact of 8,000 jobs and $630 million, including more than $270 million in taxes (Statistics Canada 2007, 2008).

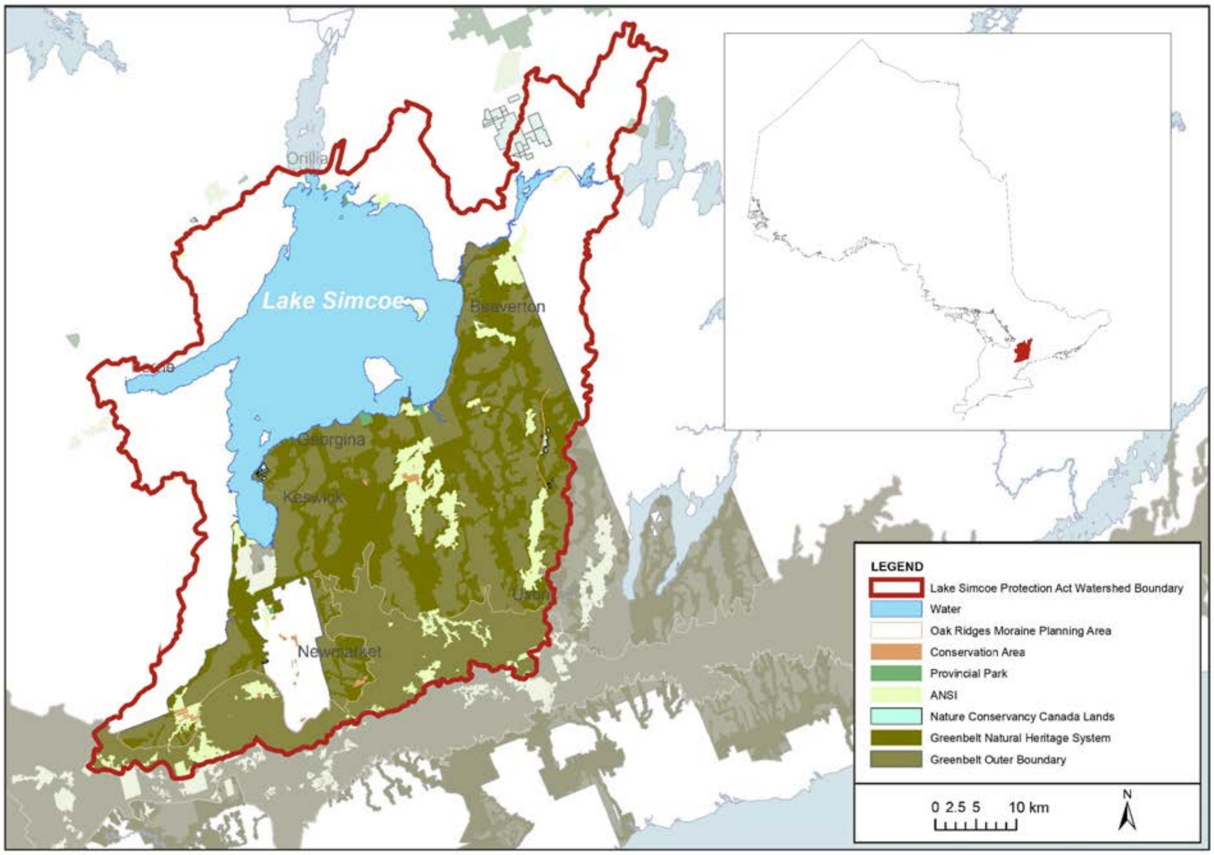

Figure 1. *Natural heritage areas and selected land use designations in and adjacent to the Lake Simcoe watershed in Ontario.*

Table 1. *Natural heritage areas located in the Lake Simcoe watershed (sources: LIO 2008, NCC 2008, Gray et al. 2009).*

Natural heritage area designation	Management authority	Total number of areas	Total area (ha) (% of watershed)
Provincial parks	Ontario Parks	6	706.2 (0.21%)
Conservation areas	Lake Simcoe Conservation Authority	30	911.0 (0.28%)
Areas of natural and scientific interest	Lakes Simcoe Conservation Authority, Ontario Ministry of Natural Resources on Crown land, private land owners, land trusts, etc.	27	12,016.8 (3.64%)
Candidate areas of natural and scientific interest	Lakes Simcoe Conservation Authority, Ontario Ministry of Natural Resources for ANSIs on Crown land, private land owner, land trusts, etc.	25	5,607.6 (1.70%)
Private properties managed by non-government organizations	Various (e.g., Nature Conservancy of Canada)	49	3,373.0 (1.02%)
Total		137	22,614.6 (6.85%)

3.0 The Role of Vulnerability Assessment in Adaptive Management

It is possible that the current changes—warming and increased variability—in Earth's climate will continue for decades, perhaps centuries, and will affect the way Ontarians engage in sustainable management of natural assets in the province's ecosystems. In response to climate change, agencies and organizations will need to 'learn while doing' (Lee 1999) to help adapt management decisions as ecosystems change. It is anticipated that effective natural asset planning and management will aim to maintain ecological sustainability, will need to be socially acceptable, and will address the known and potential vulnerability of ecological and socio-economic assets to climate change.

While agreement about the need to actively manage for climate change and to develop and integrate risk management strategies into current and new programs is widespread, adaptive processes are only now being described and operationalized (see Gleeson et al. 2011). An adaptive management process includes the following steps: (1) assess readiness and capacity to respond, (2) conduct vulnerability analyses to identify and prioritize adaptation needs, (3) develop adaptation strategies, and (4) monitor adaptation success and determine if vulnerabilities have been reduced/eliminated (Figure 2). Here we explore the use of climate change modelling tools and techniques to complete steps 2 to 4 of an adaptive management process in relation to natural heritage areas and nature-based tourism in the Lake Simcoe watershed.

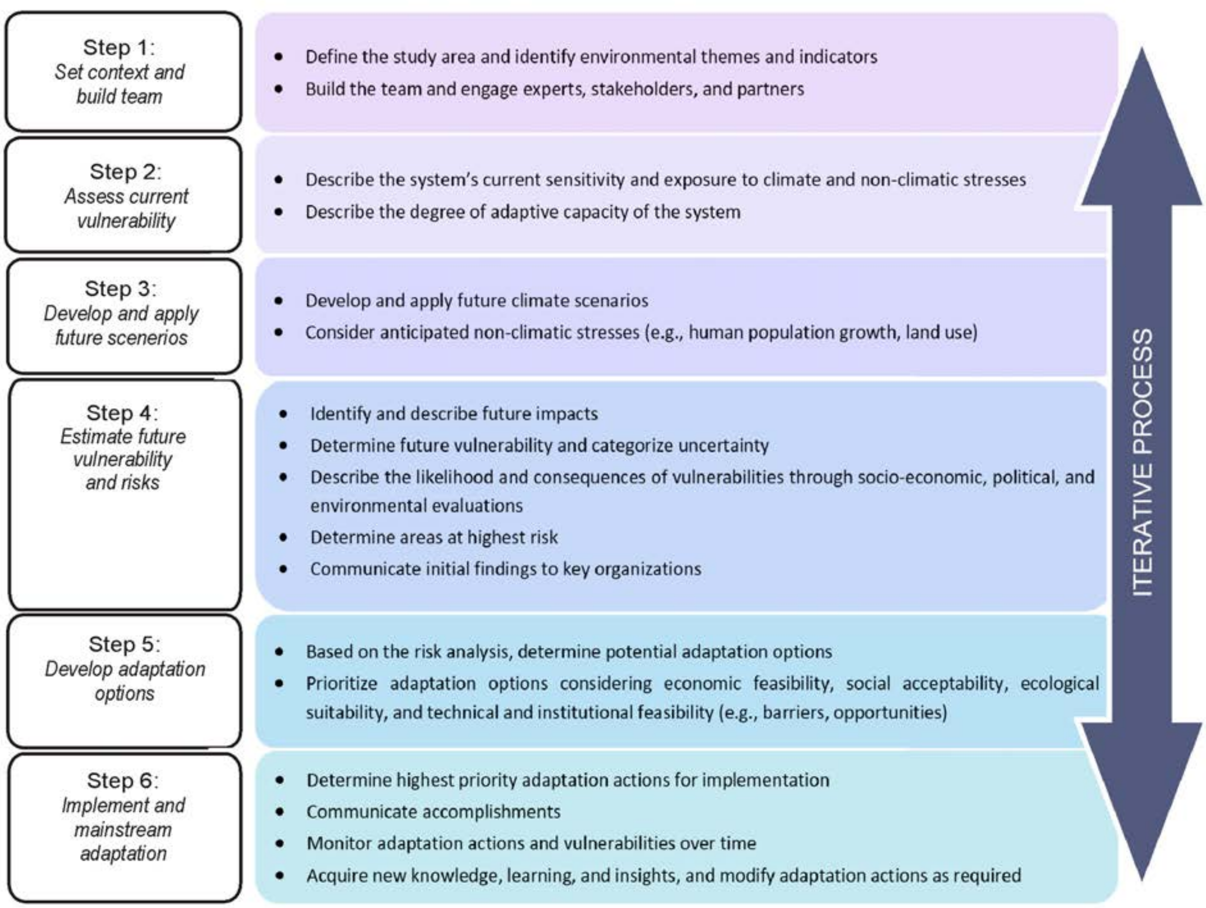

Figure 2. *Steps in the vulnerability assessment to inform development of a climate change adaptation strategy for the Lake Simcoe watershed (Source: Gleeson et al. 2011).*

4.0 Methods

4.1 Natural heritage areas

Plants and animals inhabit areas in which the *climate envelope* (i.e., unique meteorological conditions created by temperature, precipitation, and wind patterns) meets their physiological and environmental (e.g., light, water, temperature, and nutrients) needs. Based on work by McKenney et al. (2007; 2011a, b), current and projected climate envelopes were generated for tree species with a known range of climate and site type preferences using version 3 of the Canadian Coupled Global Climate Model (CGCM3) and the A2 and B1 scenarios (maps showing projections for several common climate models, scenarios, and timeframes are available on the NRCan website; e.g., for black spruce (*Picea mariana*) *http://planthardiness.gc.ca/index.pl?m=9&lang=en&speciesid=1000796*). The A2 scenario assumes higher greenhouse gas levels by 2100, a high human population(~15 billion) and reduced environmental protection, while the B1 scenario assumes a low human population (~billion) and a higher level of environmental protection (Nakićenović et al. 2000). The mapped climate envelopes illustrate the change in climate conditions for each tree species in three 30-year periods (2011-2040, 2041-2070, and 2071-2100) derived from a 30-year baseline period (1971-2000). We used the projected distribution of tree species as a proxy indicator of vulnerability of ecosystems in natural heritage areas to climate change. For each time period, the presence or absence of a desirable climate envelope for each tree species in 63 of the natural heritage areas in the Lake Simcoe watershed was used to inform development of a vulnerability statement.

4.2 Nature-based tourism

We used season length for four winter activities (i.e., ice fishing, alpine skiing, Nordic skiing, and snowmobiling) and park visitation patterns as indicators of vulnerability of nature-based tourism to climate change in the Lake Simcoe watershed. For example, in recent years, ice fishing in the watershed has been affected by two climate-related phenomena: the pressure crack on Lake Simcoe during the 1996-97 winter season (a safety issue) and the shortened ice fishing season during the late 1990s (particularly 1997-98 and 1998-99). Scott et al. (2002) used the 1997-98 and 1998-99 ice fishing seasons as analogues to describe the potential effect of climate change on ice fishing opportunities.

The potential effects of climate change on the length of the season for ice fishing, alpine skiing, Nordic skiing, and snowmobiling were explored by evaluating the projections from several climate model scenario combinations that were also used by Scott et al. (2002), McBoyle et al. (2007), and Gilmour (2009) to evaluate effects of climate change on recreational activities in Ontario and Canada. Climate models included versions 1 and 2 of the Canadian Coupled Global Climate Model (CGCM1 and CGCM2), a British model (HadCM3), an American model (NCARPCM), an Italian model (INMCM3), and two Japanese models (CCSRNIES and MIROC3.2) (for details see Nakićenović et al. 2000 and Solomon et al. 2007).

We used regression analysis techniques described by Jones and Scott (2006a) to examine the relationship between climate change and park visitation. Ontario Parks defines *visitation* as: (1) people entering parks by vehicles with daily vehicle permits (average occupants per vehicle by number of permits), (2) camper nights (number of regular and backcountry campers by nights stayed), and (3) number of people entering for free day use (Ontario Parks 2010). Following Jones and Scott (2006a), maximum monthly temperature (Tmax) was selected as the predictor of visitation patterns and used to create single variable regression equations. Note that while people are more likely to participate in outdoor recreation activities on warm days (particularly during shoulder seasons), engagement is also a function of leisure time availability, institutional seasonality (i.e., patterns of holiday taking), and supply (i.e., number of parks and their operating seasons). Although the regression models do not account for these variables, we feel that they provide a reasonable approximation of potential increased activity under projected climate change.

Single variable regression equations were developed with six years of monthly park visitation data (2004 to 2010) for Sibbald Point and McCrae Point provincial parks. Based on a curve fitting procedure completed by Jones and Scott (2006a), we used cubic regression to describe the relationship between visitor numbers and shoulder season climate and linear regression to describe the relationship between climate and the peak summer season (Figures 3 and 4; Table 2). Monthly climate data (Tmax) obtained from the weather station in each park for the period 1971 to 2000 were used to create a 30-year baseline against which future climate change scenarios could be compared. The Tmax projections derived from the CGCM3-A2 and -B1 model-scenario combinations for the 2020s, 2050s, and

2080s were incorporated into the algorithms to project changes in visitor numbers. In addition, we projected the combined effect of demographic change and climate change for the three time periods for both parks.

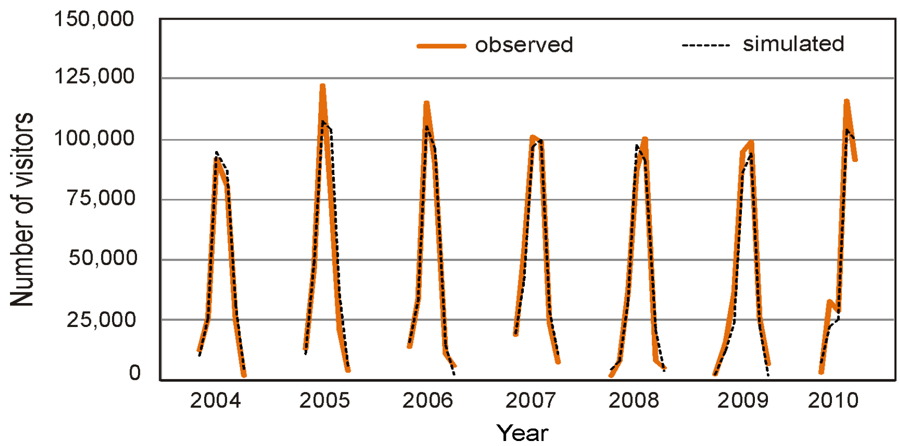

Figure 3. *Observed and simulated seasonal visitation to Sibbald Point Provincial Park in Ontario for a seven-year period based on the combined results from one-variable (monthly maximum temperature - Tmax) cubic and linear regression equations.*

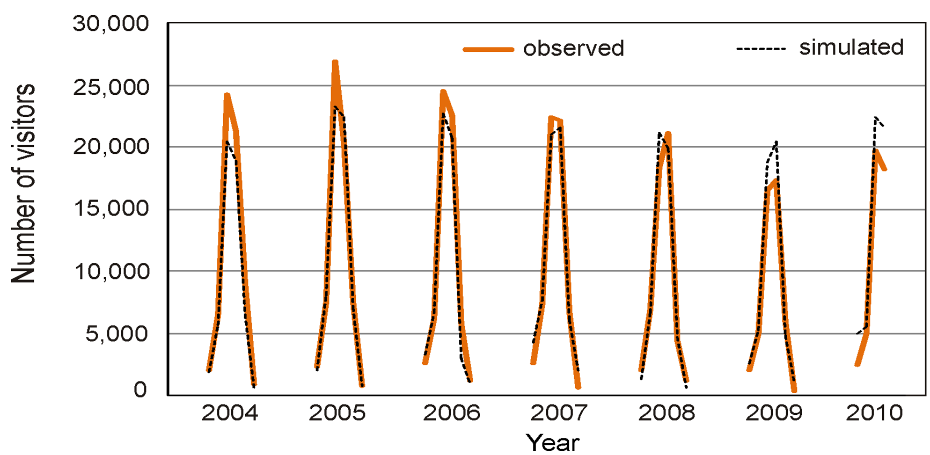

Figure 4. *Observed and simulated seasonal visitation to McCrae Point Provincial Park in Ontario over a seven-year period based on the combined results from one-variable (monthly maximum temperature - Tmax) cubic and linear regression equations.*

Table 2. *Regression models of the relationship between climate (represented by mean monthly maximum temperature [Tmax]) and natural heritage area visitation in the Lake Simcoe watershed.*

Natural heritage area	Model[1,2]	Climatic predictor of visits	Model type[3]	r^2	Equation used in assessment (visits =)[4]
Sibbald Point Provincial Park	S	Tmax	C	0.90	$= 4.01x^3 - 26.22x^2 - 135.02x + 1527.60$
	P		L	0.25	$= 4609.63x - 17109.46$
McRae Point Provincial Park	S	Tmax	C	0.83	$= -5.89x^3 + 351.73x^2 - 6169.69x + 34296.44$
	P		L	0.22	$= 952.24x - 2581.13$

[1]Model: S = shoulder season, P = peak season. [2]Methodological note: The model was truncated at specific temperature thresholds when visitation was zero (7 °C).
[3]Model type: C = cubic regression, L = linear regression. [4]x = mean monthly maximum temperature (Tmax).

5.0 Results

5.1 Natural heritage areas

As the century progresses, an increase in average temperature is projected for all natural heritage areas in the watershed. For example, McKenney et al. (2010a) projected that in Sibbald Point Provincial Park the daily minimum temperature of the coldest month will warm by 7 °C and the daily maximum temperature of the warmest month will increase by almost 6 °C. In addition, periods of warmer weather will be longer. For example, by the end of the century the growing season in Sibbald Point Provincial Park is projected to increase by 35 days (Table 3). The magnitude of these changes will significantly affect both the ecology and socio-economics of the area.

Table 3. *Current and projected future climate for Sibbald Point Provincial Park and McCrae Point Provincial Park based on the CGCM3-A2 model-scenario combination (Source: data interpreted from McKenney et al. 2010a; see also McKenney et al. 2011b).*

Climate variable	Period			
	1971-2000	2010-2040	2041-2070	2071-2100
Sibbald Point Provincial Park				
Mean temperature - annual (°C)	6.5	8.4	9.8	11.5
Mean max. temperature - warmest month (°C)	26.4	29.3	30.5	32.2
Mean min. temperature - coldest month (°C)	-13.3	-10.8	-8.0	-5.9
Mean diurnal range (°C)	10.0	9.5	9.3	9.2
Annual temperature range (°C)	34.7	40.2	38.4	38.1
Growing season start - Julian date	107	97	94	8.6
Growing season end - Julian date	318	327	332	338
Growing season length (days)	218	231	239	253
Growing season mean temperature (°C)	10.7	15.0	15.0	16.0
Growing season temperature range (°C)	27.0	30.0	31.0	33.0
Precipitation - annual (mm)	873	882	907	968
Precipitation - warmest quarter (mm)	242	232	232	218
Precipitation - coldest quarter (mm)	193	216	216	260
McCrae Point Provincial Park				
Mean temperature - annual (°C)	6.2	8.2	9.6	11.2
Mean max. temperature - warmest month (°C)	26.1	29.0	30.2	31.9
Mean min. temperature - coldest month (°C)	-14.2	-11.7	-8.8	-6.7
Mean diurnal range (°C)	10.2	9.6	9.4	9.3
Annual temperature range (°C)	40.3	40.7	38.8	38.6
Growing season start - Julian date	108.0	98.0	95.0	87.0
Growing season end - Julian date	317.0	326.0	331.0	337.0
Growing season length (days)	210.0	229.0	237.0	251.0
Growing season mean temperature (°C)	13.0	14.0	15.0	16.0
Growing season temperature range (°C)	27.0	30.0	31.0	33.0
Precipitation - annual (mm)	969.0	949.0	977.0	1050
Precipitation - warmest quarter (mm)	248.0	233.0	225.0	217.0
Precipitation - coldest quarter (mm)	242.0	252.0	261.0	311.0

The occurrence of natural heritage areas with climate suitable for existing tree species survival varies greatly (Tables 4 and 5). For example, the amount of area with suitable climate is projected to decrease for boreal species such as black spruce (Figure 5), white spruce (*Picea glauca*), balsam fir (*Abies balasamea*), but increase for species such as willow oak (Figure 6), tulip tree (*Liriodendron tulipifera*), and shagbark hickory (*Carya ovata*) that are currently growing in more southerly locations. While many uncertainties are associated with the use of this indicator [see Aitken et al. (2008) and McKenney et al. (2010b)], results suggest the potential for substantial changes in the distribution of many tree species' climate envelopes in the Lake Simcoe watershed. More complex modelling approaches imply the same result (McKenney et al. 2011a).

Table 4. *Gains and losses of suitable climate envelope representation for tree species relative to the 1971-2000 baseline in selected Lake Simcoe Watershed natural heritage areas for three time periods using the CGCM3-A2 climate model-scenario combination. Results are shown for full climatic ranges only.*

Natural heritage area and time period	Projected # of species gained relative to baseline	Projected # of species lost relative to baseline	Projected number (percentage[1]) of species present in time period compared to baseline
Watershed Boundary – Species present at baseline (1971-2000) = 104			
2020s	+15	-1	118 (+13)
2050s	+19	-6	117 (+13)
2080s	+16	-22	98 (-6)
McRae Point Provincial Park – Species present at baseline (1971-2000) = 95			
2020s	+13	-4	104 (+9)
2050s	+21	-10	106 (+12)
2080s	+21	-25	91 (-4)
Sibbald Provincial Park – Species present at baseline (1971-2000) = 100			
2020s	+15	-5	110 (+10)
2050s	+15	-15	100 (0)
2080s	+19	-29	90 (-10)
Beaverton Alvar and Wetlands ANSI – Species present at baseline (1971-2000) = 97			
2020s	+11	-5	103 (+6)
2050s	+18	-11	104 (+7)
2080s	+21	-26	92 (-5)
Zephyr Creek Wetlands – Species present at baseline (1971-2000) = 100			
2020s	+14	-5	109 (+9)
2050s	+14	-16	98 (-2)
2080s	+19	-29	90 (-10)

[1] Percentages have been rounded

Table 5. *Current and future presence/absence (1/0) of suitable climate habitat (full range only) for selected tree species in the Lake Simcoe watershed using the CGCM3-A2 climate model-scenario combination.*

Tree species	Period			
	1971-2000	2011-2040	2041-2070	2071-21000
Black spruce	1/0	1/0	1/0	0/0
White spruce	1/0	1/0	1/0	0/0
Balsam fir	1/1	1/0	1/0	0/0
Tulip tree	1/0	1/0	1/0	1/0
Shagbark hickory	1/0	1/0	1/0	1/0
Willow oak	0/1	0/1	1/1	1/1
Sugar maple	1/0	1/0	1/0	1/0

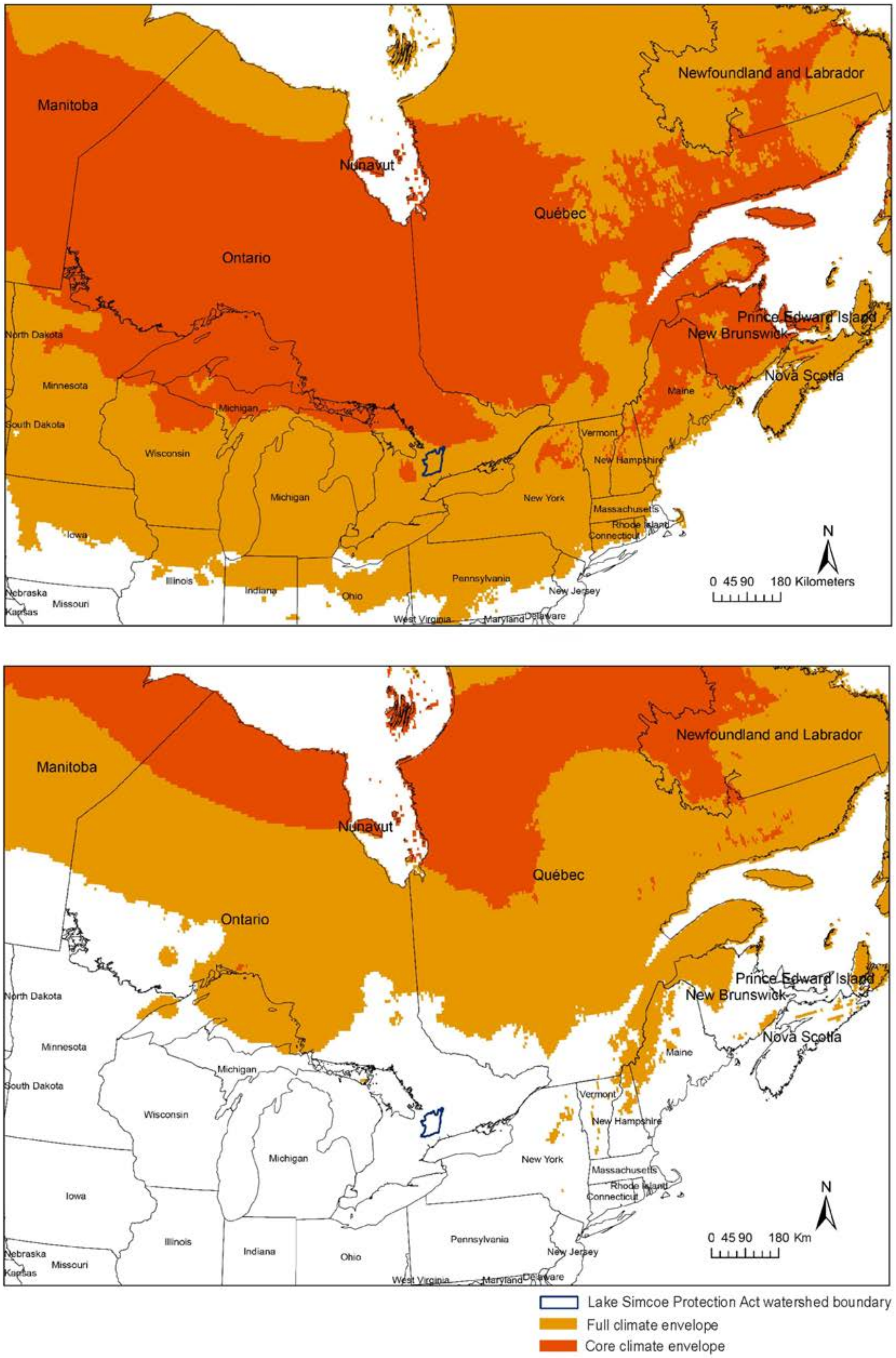

Figure 5. *An example illustrating the potential loss of representative climate conditions for black spruce in Ontario (top = 1971-2000; bottom = 2071-2100 climate envelope using the CGCM3-A2 climate model-scenario combination) (Source: http://planthardiness.gc.ca/index.pl?m=9&lang=en&speciesid=1000796).*

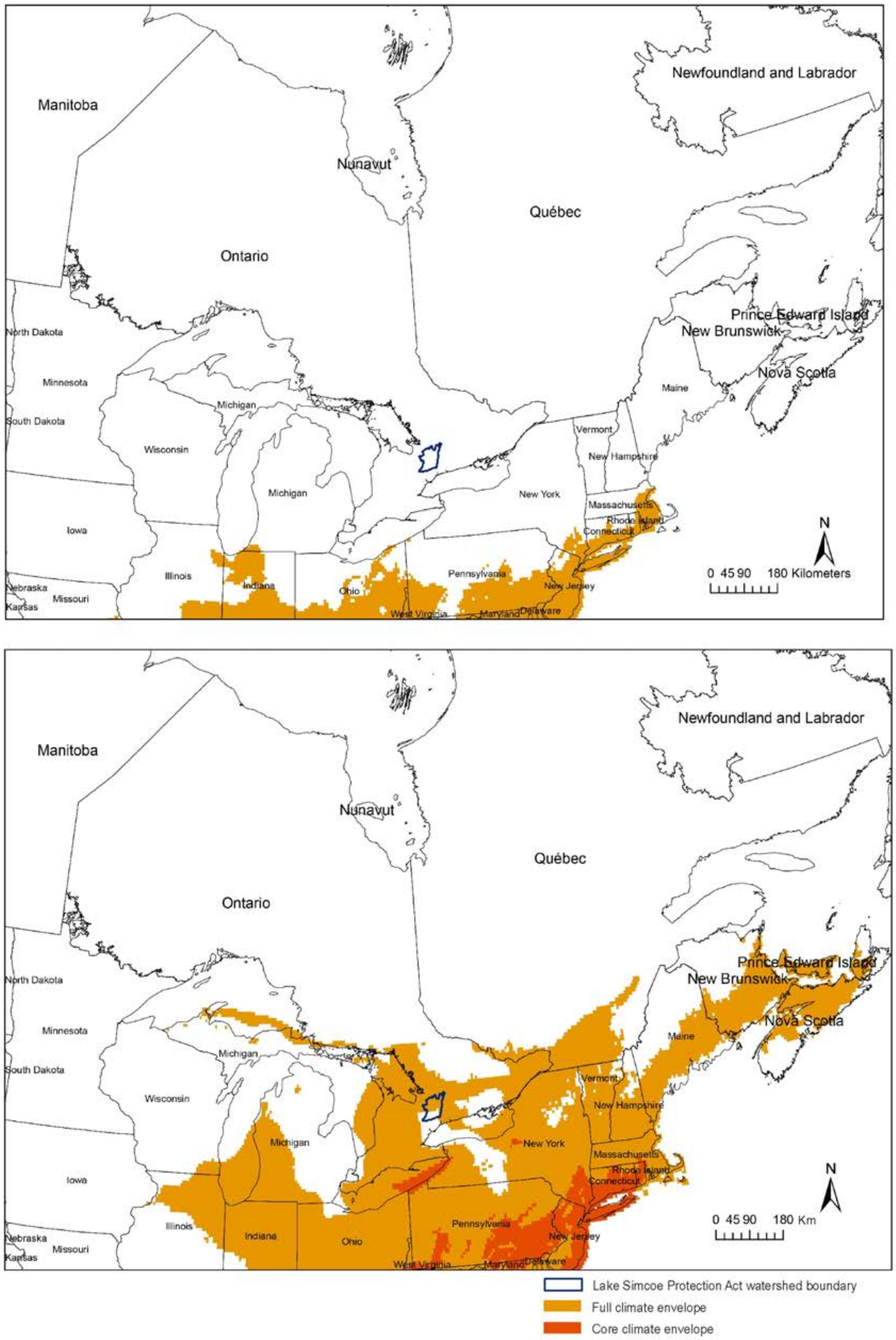

Figure 6. *An example illustrating the potential gain of representative climate conditions for willow oak in Ontario (top = 1971-2000; bottom = 2071-2100 climate envelope using the CGCM3-A2 climate model-scenario combination) (Source: http://planthardiness.gc.ca/index.pl?m=9&lang=en&speciesid=1000959).*

5.2 Nature-based tourism

Ice fishing: The average winter temperature in the Great Lakes region in 1997-98 was 3.7 °C above normal, and the Lake Simcoe ice fishing season during that winter was 52% shorter (based on average of four sample sites) than the winter of 2000-01 when temperatures were 0.3 °C below normal. Projected winter temperatures based on the CGCM1-IS92a model-scenario combination for the 2050s exceeded the 1997-98 temperatures by more than 1 °C, which translates into an average winter temperature that is about 4.8 °C warmer, suggesting that the length of the ice fishing season could be further reduced as the century progresses (Scott et al. 2002). In the second example, the winter of 1998-99 was 2.7 °C warmer than normal and the ice fishing season was 32% shorter (based on an average of five sample sites) than the winter of 2000-01. For 1998-99, the temperature deviation from the 1961 to 1990 normal is a reasonable analogue for the CGCM2-IS92a 2020s model-scenario combination (+2.97 °C) and slightly higher than the HadCM3-IS92a 2050s model-scenario results (+2.06 °C).

Alpine skiing: Projections from both the CGCM1-IS92a and HadCM3-IS92a model-scenario combinations indicated that the alpine ski season in the Lakelands Tourism Region adjacent to the western and northern boundaries of the Lake Simcoe watershed will be significantly shorter by the end of the century (Table 6) and snowmaking costs will increase. Even with improved snowmaking capacity, model results suggest that the alpine ski industry will be increasingly challenged to achieve a 12-week ski season (Table 7), a benchmark for economic viability (Scott et al. 2002).

Table 6. *Ski season projections for resorts in the Lakeland Tourism Region[1] based on current and improved[2] snowmaking technology using the Canadian Coupled Global Climate Model (CGCM1) and the Hadley Climate Model (HadCM3) with the IS92a emissions scenario (Source: Scott et al. 2002).*

Ski area and snowmaking technology	Simulated baseline (days)	Change in season length by days (%)					
		CGCM1			HadCM3		
	1961-1990	2020s	2050s	2080s	2020s	2050s	2080s
Hidden Valley	126						
Current		-14	-26	-39	-9	-16	-30
Improved		-10	-20	-30	-6	-11	-22
Sir Sam’s	125						
Current		-14	-24	-38	-10	-16	-30
Improved		-10	-18	-29	-6	-12	-22
Horseshoe	118						
Current		-15	-31	-47	-8	-18	-36
Improved		-7	-20	-34	-3	-10	-25
Blue Mountain	120						
Current		-30	-52	-66	-18	-30	-54
Improved		-17	-32	-49	-10	-19	-39
Talisman[3]	125						
Current		-22	-38	-54	-16	-25	-40
Improved		-14	-26	-38	-10	-17	-31
Average	123						
Current		-19	-34	-49	-12	-21	-38
Improved		-12	-23	-36	-7	-14	-28

[1]Although these ski areas are not in the Lake Simcoe watershed, they are close enough to approximate potential impacts under a changing climate.
[2]Current and improved technology refers to projected terrain enhancements and snowmaking capabilities.
[3]Talisman is no longer in operation.

Table 7. *Projected effects of a warmer climate on the probability of a 12-week ski season at the Horseshoe Ski Area using the Canadian (CGCM1) and British (HadCM3) climate models with the IS92a emissions scenario compared to the 1961-1990 baseline (Source: Scott et al. 2002).*

Period	Current snowmaking technology		Improved snowmaking technology	
	CGCM1	HadCM3	CGCM1	HadCM3
2020s	93	100	100	100
2050s	55	89	86	100
2080s	3	34	38	66

Nordic skiing: Assuming that snow conditions on most winter trails will not be supplemented with snowmaking equipment, Nordic skiing in the Lake Simcoe watershed will be more sensitive to climate change than alpine skiing. For example, the length of the Nordic skiing season in the 2020s (2011-2040) is projected to be 39% shorter based on the HadCM3-IS92a and 55% shorter based on the CGCM1-IS92a model-scenario combinations. End of century projections suggest that the season will be 79% (HadCM3-IS92a) to 86% (CGCM1-IS92a) shorter (Table 8).

Table 8. *Observed and simulated Nordic ski season length (days) in the Lakelands Tourism Region, 1980s to 2080s using the Canadian (CGCM1) and British (HadCM3) climate models with the IS92a emissions scenario (Source: Modified from Scott et al. 2002).*

Nordic ski area and climate model[1]	Baseline period	Simulated season length[2] in days (percentage change)		
	1961-1990	2020s	2050s	2080s
Horseshoe[3]	88			
CGCM1		36 (-59)	14 (-84)	8 (-91)
HadCM3		42 (-52)	31 (-65)	12 (-86)
Haliburton	94			
CGCM1		51 (-46)	31 (-67)	21 (-78)
HadCM3		71 (-24)	56 (-40)	35 (-63)
Duntroon	73			
CGCM1		29 (-60)	16 (-78)	10 (-86)
HadCM3		51 (-30)	37 (-49)	14 (-81)
Mansfield2	88			
CGCM1		36 (-59)	14 (-84)	8 (-91)
HadCM3		42 (-52)	31 (-65)	12 (-86)
Hardwood Hills[3,4]	88			
CGCM1		36 (-59)	14 (-84)	8 (-91)
HadCM3		42 (-52)	31 (-65)	12 (-86)
Muskoka	102			
CGCM1		52 (-49)	32 (-69)	22 (-79)
HadCM3		76 (-25)	56 (-45)	29 (-72)
Average % Δ	89			
CGCM1		40 (-55)	20 (-78)	13 (-86)
HadCM3		54 (-39)	40 (-55)	19 (-79)

[1]The IS92a scenario was used with each climate model.
[2]Season length is estimated using a climate threshold based on a combination of maximum temperature, minimum temperature, rain, and natural snow depth.
[3]Analysis for Horseshoe, Mansfield, and Hardwood Hills Nordic ski areas was based on a common climate station and therefore the projected season length for each climate change scenario was identical.
[4]Hardwood Hills is the only Nordic ski area with snowmaking capacity for the entire trail network.

Snowmobiling: Results of climate change scenario projections indicate substantial reductions in the length of the snowmobiling season in the Orillia Ontario Federation of Snowmobile Club (OFSC) Snowmobile District 8 (Table 9). Even results from the 2011 to 2040 CGCM1-IS92a model-scenario combination used by Scott et al. (2002) indicate that the snowmobile season rarely reaches the lower end of the OFSC estimated historical season range and on average will be 46% shorter than the 1961 to 1990 baseline. For the same period, the HadCM3-IS92a model-scenario combination projected a 38% shorter season. During the 2041 to 2070 period, a 73% reduction in average season length is projected by the CGCM1-IS92a model-scenario combination and a 51% reduction is expected under the HadCM3-IS92a model-scenario combination. By the end of the century, projections indicate a season reduction of 77% (HadCM3-IS92a) and 84% (CGCM1-IS92a). The climate model scenarios used by McBoyle et al. (2007) and Gilmour (2009) suggest even shorter snowmobile seasons as the century progresses. In addition, changes in the duration and extent of ice cover could also increase the risk to outdoor enthusiasts who depend on lake ice for travel.

Table 9. *Snowmobiling season length (days)[1] and percent reduction (in brackets) from the 1961-1990 baseline for Ontario Federation of Snowmobile Clubs, District 8 (Orillia) using a variety of climate model-scenario combinations[2].*

Snow depth	Model-scenario	Season length		
		2020s	2050s	2080s
15 cm	[3]HadCM3-IS92a	48 (-38)	38 (-51)	18 (-77)
	[3]CGCM1-IS92a	42 (-46)	21 (-73)	12 (-84)
	[4]NCARPCM-B21	39 (-49)	30 (-61)	N/A
	[4]CCSRNIES-A11	22 (-66)	1 (-99)	N/A
	[5]INMCM3.0-B1	26 (-66)	24 (-69)	23 (-70)
	[5]MIROC3.2-A1B	12 (-84)	7 (-91)	5 (-94)
30 cm	[5]INMCM3.0-B1	14 (-82)	11 (-86)	10 (-87)
	[5]MIROC3.2-A1B	3 (-96)	2 (-97)	1 (-99)

[1]Average modeled season length for OFSC District 8 based on 1961-1990 baseline (15 cm) = 77 days (Scott et al. 2002).

[2]Models and scenarios used were:

- HadCM3 – Version 3 of the Hadley Centre Coupled Model, United Kingdom.
- CGCM1 – Version 1 of the Canadian Coupled Global Climate Model.
- NCARPCM – National Center for Atmospheric Research (NCAR), USA.
- CCSRNIES – Center for Climate Research Studies (CCSR) and National Institute for Environmental Studies (NIES), Japan.
- INMCM3.0 – National Institute of Geophysics and Volcanology, Italy.
- MIROC3.2 – Meteorological Institute for Environmental Studies, Japan.
- IS92a – Medium to high emission scenario developed in 1992 by the IPCC.
- A1 – Higher emission scenarios.
- B1 – Lower emission scenarios.
- B2 – Medium emission scenarios.

[3]Scott et al. (2002)
[4]McBoyle et al. (2007)
[5]Gilmour (2009)

Park visitation: Changes in the length and quality of seasons will affect visitation patterns, revenue, and management requirements. This trend has been verified in the United States by Buckley and Foushee (2011) who reported that peak attendance in national parks now occurs four days earlier than in 1979 in response to warmer spring temperatures. Two recent analyses indicate that due to a longer warm-weather tourism season, Canada's natural heritage areas could experience an increase in visitors under climate change (Jones and Scott 2006a,b). For example, Jones and Scott (2006a) projected that overall visitation levels to Ontario Provincial Parks could increase 11 to 27% in the 2020s and 15 to 56% in the 2050s, with the largest increases in visitation occurring during the spring and fall months as conditions conducive to warm-weather recreation activities begin earlier and last longer.

Park visitation is traditionally highest in summer. For example, 72% and 67% of all visitors to Sibbald Point and McRae Point provincial parks, respectively, use these parks in July and August (Figure 7). In winter, many amenities in Sibbald Point Provincial Park are not available and McCrae Point Provincial Park is closed. Following the techniques reported by Jones and Scott (2006a), the one-variable (Tmax) regression equations were used to generate projected visitation numbers to the end of the century based on A2 and B1 scenarios. Results indicate that visitation will increase during July and August in both parks (Tables 10-13; Figure 8). For the 2020s, annual visits to Sibbald Point Provincial Park are projected to increase between 12% (B1 scenario) and 13% (A2 scenario). At mid-century, scenario results diverge, with the A2 scenario indicating greater increases in visitation for the 2050s (+28%) and 2080s (+48%). Similar trends are projected for McRae Point Provincial Park with visitation increases of 10% (2020s), 15 and 20% (2050s), and 18 and 31% (2080s), based the B1 and A2 scenarios, respectively. When projected visitor numbers influenced by climate change are added to those influenced by human population growth in and around the Lake Simcoe watershed, the projected demand for access to parks and other natural heritage areas is expected to be even greater (Table 14).

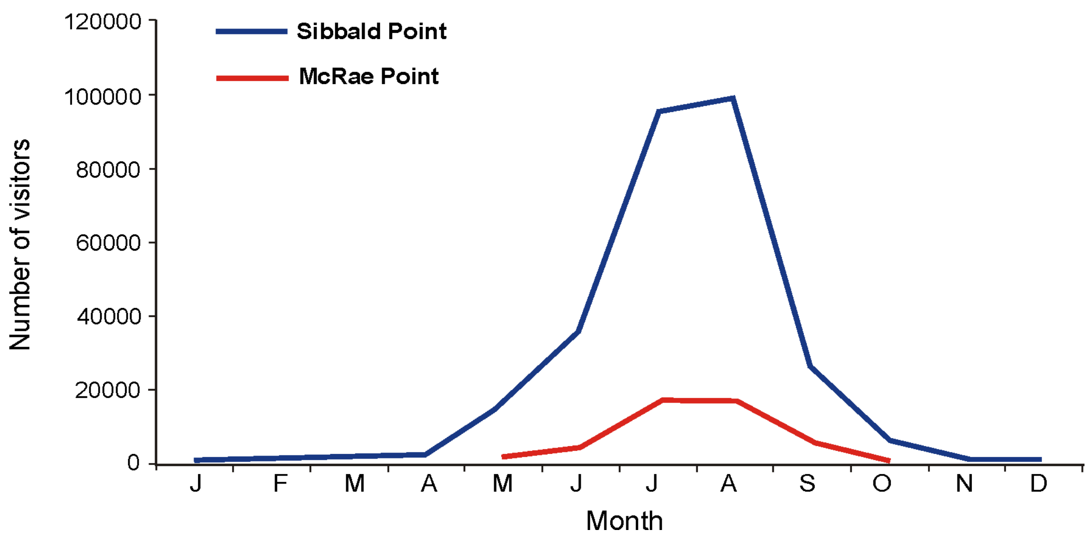

Figure 7. *Seasonal visitation patterns (number of monthly visitors) at Sibbald Point and McRae Point provincial parks in 2009 (Ontario Parks 2010).*

Table 10. *Projected effect of climate change on the annual number of visitors (percentage in parentheses) to Sibbald Point Provincial Park (CGCM3-A2 model-scenario).*

Month	Baseline (1971-2000)	Change in number of visitors (%)		
		2020	2050	2080
January	0	0	0	0
February	0	0	0	0
March	0	23	75	593
April	1,752	3,249 (+85)	4,610 (+163)	7,450 (+325)
May	13,642	17,685 (+30)	23,307 (+71)	30,155 (+121)
June	39,577	46,968 (+19)	56,978 (+44)	70,149 (+77)
July	110,864	116,852 (+5)	124,964 (+13)	134,563 (+21)
August	106,968	116,155 (+9)	122,623 (+15)	132,604 (+24)
September	27,643	35,767 (+29)	44,154 (+60)	56,888 (+105)
October	5,425	8,068 (+49)	12,433 (+129)	18,489 (+241)
November	348	872 (+150)	1,287 (+269)	2,391 (+586)
December	0	0	0	0
Annual	306,218	345,639 (+13)	390,432 (+28)	453,282 (+48)

Table 11. *Projected effect of climate change on the annual number of visitors (percentage in parentheses) to Sibbald Point Provincial Park (CGCM3-B1 model-scenario).*

Month	Baseline (1971-2000)	Change in number of visitors (%)		
		2020	2050	2080
January	0	0	0	0
February	0	0	0	0
March	0	0	25	47
April	1,752	2,770(+58)	3,853 (+120)	4,338 (+148)
May	13,642	17,250 (+27)	19,991 (+47)	21,288 (+56)
June	39,577	47,645 (+20)	50,614 (+28)	52,851 (+34)
July	110,864	117,435 (+6)	120,734 (+9)	123,961 (+12)
August	106,968	114,383 (+7)	119,486 (+12)	121,423 (+14)
September	27,643	34,661 (+25)	38,704 (+40)	44,548 (+61)
October	5,425	8,740 (+61)	9,806 (+81)	11,106 (+105)
November	348	804 (+131)	1,028 (+195)	1,128 (+224)
December	0	0	0	0
Annual	306,218	343,689 (+12)	364,240 (+19)	380,691 (+24)

Table 12. *Projected effect of climate change on the annual number of visitors (percentage in parentheses) to McRae Point Provincial Park (CGCM3-A2 model-scenario).*

Month[1]	Baseline (1971-2000)	Change in number of visitors (%)		
		2020	2050	2080
May	2,720	3,755 (+38)	4,989 (+83)	6,233 (+129)
June	7,359	7,895 (+7)	8,060 (+10)	7,642 (+4)
July	23,855	25,092 (+5)	26,768 (+12)	28,751 (+21)
August	23,050	24,948 (+8)	26,284 (+14)	28,346 (+23)
September	5,776	6,906 (+20)	7,720 (+34)	7,991 (+38)
October	723	1,243 (+72)	2,390 (+231)	3,961 (+448)
Annual	63,484	69,840 (+10)	76,211 (+20)	82,924 (+31)

[1]Results were truncated to reflect the operating season of the park.

Table 13. *Projected effect of climate change on the annual number of visitors (percentage in brackets) to McRae Point Provincial Park (CGCM3-B1 model-scenario).*

Month[1]	Baseline (1971-2000)	Change in number of visitors (%)		
		2020	2050	2080
May	2,747	3,691 (+34)	4,327 (+58)	4,631 (+69)
June	7,386	7,954 (+8)	8,040 (+9)	8,096 (+10)
July	23,855	25,212 (+6)	25,894 (+9)	26,561 (+11)
August	23,050	24,582 (+7)	25,636 (+11)	26,036 (+13)
September	5,803	6,842 (+18)	7,302 (+26)	7,655 (+32)
October	750	1,428 (+91)	1,708 (+128)	2,059 (+175)
Annual	63,592	69,710 (+10)	72,907 (+15)	75,038 (+18)

[1]Results were truncated to reflect the operating season of the park.

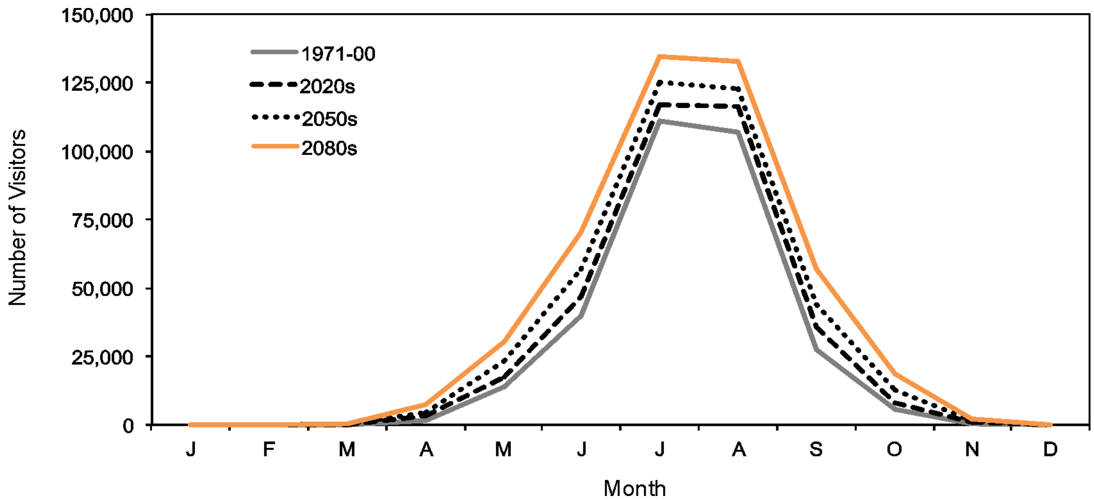

Figure 8. *Seasonal visitation patterns (number of monthly visitors) at Sibbald Point Provincial Park, projected for three time periods using the CGCM3-A2 model-scenario combination compared to 1971 to 2000 baseline.*

Table 14. *The combined effect of demographic change and climate change in the mid-2020s, -2050s, and -2080s for Sibbald Point and McCrae Point Provincial Parks.*

Park, CGCM3 scenario and time period	Baseline (total visitors – 2007)	Change in number of visitors (%1)						
		Climate change only		Demographic change[2]		Climate effect on new demographic		Climate change + demographic change[2]
	A	B[3] additional new visitors	C A+B	D additional new visitors	E A+D	F %C^{-1} x D	G B+D+F	H A+G
Sibbald A2 - 2020s	313,216	32,423	345,639 (+10)	34,767	347,983 (+11)	3,477 (+1)	70,667	383,883 (+23)
- 2050s		77,216	390,432 (+25)	34,767	347,983 (+11)	8,692 (+3)	120,675	433,891 (+39)
- 2080s		140,066	453,282 (+45)	34,767	347,983 (+11)	15,645 (+5)	190,478	503,694 (+61)
Sibbald B1 - 2020s		30,473	343,689 (+10)	34,767	347,983 (+11)	3,477 (+1)	68,717	381,993 (+22)
- 2050s		51,024	364,240 (+16)	34,767	347,983 (+11)	5,563 (+2)	91,354	404,570 (+29)
- 2080s		67,475	380,691 (+22)	34,767	347,983 (+11)	7,649 (+2)	109,891	423,107 (+35)
McCrae A2 - 2020s	61,871	7,969	69,840 (+13)	6,868	68,739 (+11)	893 (+1)	15,730	77,601 (+25)
- 2050s		14,340	76,211 (+23)	6,868	68,739 (+11)	1,580 (+3)	22,788	84,659 (+37)
- 2080s		21,053	82,924 (+34)	6,868	68,739 (+11)	2,335 (+4)	30,256	92,127 (+49)
McCrae B1 - 2020s		7,839	69,710 (+13)	6,868	68,739 (+11)	893 (+1)	15,600	77,471 (+25)
- 2050s		11,036	72,907 (+18)	6,868	68,739 (+11)	1,236 (+2)	19,140	81,011 (+31)
- 2080s		13,167	75,038 (+21)	6,868	68,739 (+11)	1,442 (+2)	21,477	83,348 (+35)[4]

[1]All percentages are rounded up.
[2]Note: The combined effect of climate change and demographic change was projected using the following formula: $TV_{2020s} = \Sigma N_{2007}\ \Delta N_{\Delta climate}\ \Delta N_{\Delta demography}\ \Delta N_{(\Delta climate\ demograhy)}$, where

- TV_{2020s} = Projected total visitors in the 2020s
- N_{2007} = Total Visitors in 2007
- $\Delta N_{\Delta climate}$ = Change in number of visitors projected using monthly maximum temperature in linear and cubic regressions
- $\Delta N_{\Delta demography}$ = Change in number of visitors resulting from human population growth in and around the Lake Simcoe watershed
- $\Delta N_{(\Delta climate\ \Delta demograhy)}$ = Additional visitors calculated from the future time period demographic

[3]The demographic change projections are based on a 13% increase in Ontario visitors (representing 90% of all 2007 annual visits) and a 6% decrease in American visits (representing 10% of 2007 annual visits).
[4]The following example for McRae Provincial Park illustrates how the calculation works: TV_{2020s} = 61,871 + 7,839 + 6,868 + 893 = 77,471, or an increase 15,600 visitors in response to the combined effects of climate change and increasing human population in the area.

6.0 Discussion

Due to its proximity to the Greater Toronto Area, Barrie, and other communities, the human population in the Lake Simcoe watershed will continue to grow at a rapid rate (Ontario Growth Secretariat 2009; Ministry of Infrastructure 2010). The cumulative effects of rapid climate change and urbanization will present challenges and opportunities for agencies and organizations responsible for the care of natural heritage areas and the perpetuation of nature-based tourism.

6.1 Natural heritage areas

Climate change threatens the long-term existence of many species that inhabit natural heritage areas because their current climate envelope may disappear, which in turn will require changes in the planning and management programs established to protect them. Lemieux et al. (2010, 2011) identified several potential climate change-induced policy and management issues requiring attention by Canadian natural heritage area managers in the 21st century, many of which are relevant to the Lake Simcoe watershed:

- Intervening landscapes and waterscapes between formally protected natural heritage areas will be important for achieving species protection commitments.
- Management plans and conservation targets for natural heritage areas may require revision.
- Some natural heritage area habitats may become unsuitable for existing species (e.g., species unable to acclimatize to changing climatic and ecological conditions).
- Some natural heritage area habitat may become suitable for new/invading species (i.e., species currently occupying niches in more southerly ecosystems will move northwards).
- The climate envelopes of unwanted invasive species may extend northward and emerge as pervasive management issues in natural heritage areas.
- Current definitions of non-native/exotic species may require revision as new assemblages of species establish in Lake Simcoe watershed ecosystems.

Parks and other types of natural heritage areas will help practitioners manage for climate change. For example, natural heritage areas: (1) serve to maintain or strengthen ecological resilience, by for example providing habitat for plants and animals, (2) play a role in maintaining and renewing essential ecosystem services such as clean air and clean water, and (3) in some cases provide protection against the physical effects of extreme weather events and other climate-related factors (Lemieux et al. 2010, 2011). Furthermore, the relatively undisturbed nature of natural heritage area landscapes and waterscapes make them a valuable resource for climate change monitoring programs. Collectively, natural heritage areas are important in working towards achieving one of the primary objectives of the Lake Simcoe Protection Plan: *Improve the Lake Simcoe watershed's capacity to adapt to climate change* (Government of Ontario 2009:8).

6.2 Nature-based tourism

Climate change has implications for nature-based tourism because visitor use is strongly correlated with climate. Climate influences the physical resources (e.g., water levels, snow cover, and biodiversity) that provide the foundation for outdoor recreation opportunities (e.g., boating, Nordic skiing, and birdwatching), defines when specific activities are possible (e.g., beach use and swimming), and influences the level of visitor satisfaction (Jones and Scott 2006a,b). Given that the Lake Simcoe watershed provides significant opportunity for nature-based tourism, changes in ecosystem composition, structure, and function likely will require adaptive responses from the agencies and organizations responsible for their management. For example, any changes in season length will affect the short- and long-term viability of nature-based tourism businesses associated with golf, boating, hiking, alpine and Nordic skiing, and snowmobiling. In addition, adaptive management strategies will need to account for ongoing population and demographic changes that may redefine the most popular recreational activities.

While the length of the summer tourist season and associated increases in demand for access to parks and other natural heritage areas will generate additional revenue, ecological concerns requiring research and changes in management approaches remain (Buckley 2004, McCool and Moisey 2008, and many others). Any increase in visitors to the Lake Simcoe watershed during the peak tourism period will potentially result in pressure for increased access to park resources, which could strain the system, particularly if the parks are already operating at or near capacity during July and August. This raises several questions. For example, how will increased numbers of visitors affect ecosystem composition, structure, and function in natural heritage areas? What monitoring techniques should be used to assess visitor-induced effects? What adaptation strategies should be implemented to mitigate these effects? Are parks and other recreation areas in the watershed sufficient to meet increased demand for access to recreational opportunities and facilities during the summer months? In addition, demand for access to recreational amenities during the shoulder seasons is likely to increase substantially, especially if the A2 scenario is realized, which is possible given current greenhouse gas emission levels. Given increased demand for access to parks and other natural heritage areas for more of the year, as the century progresses natural asset managers will likely need to examine the ecological carrying capacity of these areas.

7.0 Recommendations

The following recommendations are provided to help decisionmakers plan future needs related to natural heritage areas and nature-based tourism opportunities in the Lake Simcoe watershed:

Understand visitor attitudes and values: Given changing population and demographic characteristics in the watershed, understanding why people choose particular nature-based activities will help resource managers develop or modify opportunities as the climate changes. For example, managers may be looking for guidance on how to adapt infrastructure, respond to changing recreational opportunities and preferences, and avoid or mitigate conflicts among user groups.

Optimize visitor safety: Climate-induced changes on Lake Simcoe, for example to water quality, duration of ice-cover, and air quality, will require effective climate risk management decisionmaking tools and emergency response capabilities to ensure visitor safety.

Invest in climate modelling, vulnerability assessment, and monitoring: Climate modelling and vulnerability assessments can help decisionmakers identify and implement appropriate adaptation strategies. Furthermore, integrated monitoring programs aimed at detecting and verifying changes to infrastructure (e.g., trails) and ecosystem composition, structure, and function (e.g., changes in the distribution and abundance of plants and animals) will help resource managers calibrate models and vulnerability assessments and guide ongoing adaptive decisionmaking.

Sponsor outreach programs: Outreach programs can be used to provide those living and working in the watershed with information about climate change threats and opportunities, research and monitoring needs, and mitigation/adaptation options. Such knowledge helps them to participate in future decisionmaking. Outreach can be accomplished via fact sheets, one-on-one conversations, workshops, website postings, and webinars.

Encourage and sponsor partnerships: Continued or increased collaboration among government agencies, universities, communities, and the private sector will strengthen a coordinated and integrated approach to adaptation planning and management, including innovation.

8.0 References

Aitken, S.N., S. Yeaman, J.A. Holliday, T. Wang and S. Curtis-McLane. 2008. Adaptation, migration, or extirpation: Climate change outcomes for tree populations. Evol. Appl. 1: 95-111.

Buckley, L.B. and M.S. Foushee. 2011. Footprints of climate change in US national park visitation. Internat. J. Biometeor. doi: 10.1007/s00484-011-0508-4.

Buckley, R. (ed.). 2004. Environmental Impacts for Ecotourism. CABI Publishing, Wallingford, Oxfordshire, UK. Ecotourism Series No. 2.

Gilmour, S. 2009. Ontario Snowmobile Tourism: Responses to Climate Variability and Change. Master of Environmental Studies (MES) Thesis, Faculty of Environment, University of Waterloo, ON, Canada. 133p.

Gleeson, J., P. Gray, A. Douglas, C.J. Lemieux and G. Nielsen. 2011. A practitioner’s guide to climate change adaptation in Ontario’s ecosystems. Ontario Centre for Climate Impacts and Adaptation Resources, Sudbury, ON. 74p. Available at: http://www.mnr.gov.on.ca/en/Business/ClimateChange/Publication/STDPROD_091282.html; accessed June 2012.

Government of Ontario. 2009. Lake Simcoe Protection Plan. Ont. Min. Environ., Toronto, ON. 91p. http://www.ene.gov.on.ca/environment/en/local/lake_simcoe_protection/STDPROD_075796.html#plan; accessed June 2012.

Gray, P.A., D. Paleczny, T.J. Beechey, B. King, M. Wester, R.J. Davidson, S. Janetos, S.B. Feilders and R.G. Davis. 2009. Ontario’s natural heritage areas: Their description and relationship to the IUCN protected area classification system (A provisional assessment). Ont. Min. Nat. Resour., Peterborough, ON. 356p. http://www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/288505.html; accessed June 2012.

Jones, B. and D.J. Scott. 2006a. Implications of climate change for visitation to Ontario‘s provincial parks. Leisure 30: 233-261.

Jones, B. and D.J. Scott. 2006b. Climate change, seasonality and visitation to Canada‘s national parks. J. Recreat. Admin. 24: 42-62.

[LIO] Land Information Ontario. 2008. Land Information Ontario data warehouse. Ont. Min. Nat. Resour., Peterborough, ON. http://www.mnr.gov.on.ca/en/Business/LIO/2ColumnSubPage/STEL02_168199.html; accessed October 2010.

Lee, K.N. 1999. Appraising adaptive management. Conserv. Ecol. 2(2) [online]. Available at: http://www.consecol.org/vol3/iss2/art3.

Lemieux, C.J. and D.J. Scott. 2005. Climate change, biodiversity conservation and protected areas planning in Canada. Can. Geogr. 49: 384–399.

Lemieux, C.J., T.J. Beechey, D.J. Scott and P.A. Gray. 2010. Protected Areas and Climate Change in Canada: Challenges and Opportunities for Adaptation. Canadian Council on Ecological Areas. CCEA Secretariat, Ottawa, ON. CCEA Occas. Pap. No. 19. 170p.

Lemieux, C.J., T.J. Beechey and P.A. Gray. 2011. Prospects for Canada’s protected areas in an era of rapid climate change. Land Use Policy 28: 928-941.

McBoyle, G., D. Scott and B. Jones. 2007. Climate change and the future of snowmobiling in non-mountainous regions of Canada. Manag. Leisure 12: 237-250.

McCool, S.F. and R.N. Moisey. 2008. Tourism, Recreation and Sustainability: Linking Culture and the Environment. CAB Int., Wallingford, UK. 296p.

McKenney, D., J.H. Pedlar, K. Lawrence, K. Campbell and M.F. Hutchinson. 2007. Potential impacts of climate change on the distribution of North American trees. BioScience 57: 939-948.

McKenney, D., P. Papadopol, K. Campbell, K. Lawrence and M. Hutchinson. 2010a. Regional, national and international climate modeling. Nat. Resour. Can. Sault Ste. Marie, ON. http://cfs.nrcan.gc.ca/subsite/glfc-climate/climate; accessed October 2010.

McKenney, D.W., J.H. Pedlar, K. Lawrence, P.A. Gray, S.J. Colombo and W.J. Crins. 2010b. Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario. Ont. Min. Nat. Resour., Appl. Res. Develop. Br., Sault Ste. Marie, ON. Clim. Change Res. Rep. CCRR-16. 42p.

McKenney, D.W., J. H. Pedlar, R.G. Rood and D. Price. 2011a. Revisiting projected shifts in the climate envelopes of North American trees using updated general circulation models. Glob. Change Biol. 17: 2720-2730.

McKenney, D.W., M.F. Hutchinson, P. Papadopol, K. Lawrence, J. Pedlar, K. Campbell, E. Milewska, R. Hopkinson and D. Price. 2011b. Customized spatial climate models for North America. Bull. Am. Meteor. Soc. December: 1612-1622.

Ministry of Infrastructure. 2010. Places to grow: better Choices, Brighter Future. Available at: http://www.placestogrow.ca/index.php . Accessed October, 2010.

Nakićenović, N., J. Alcamo, G. Davis, B. de Vries, J. Fenhann, S. Griffin, K. Gregory, A. Grübler, T.Y. Jung, T. Kram, E.L. La Rovere, L. Michaelis, S. Mori, T. Morita, W. Pepper, H. Pitcher, L. Price, K. Riaha, A. Roehrl, H.-H. Rogner, A. Sankovski, M. Schlesinger, P. Shukla, S. Smith, R, Swart, S. van Rooijen, N.Victor and Z. Dadi. 2000. Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. 599 pp. http://www.grida.no/climate/ipcc/emission/index.htm . Accessed October, 2010.

[NCC] Nature Conservancy of Canada. 2010. Nature Conservancy of Canada Sites in the Lake Simcoe Watershed. GIS Data provided by NCC – Ontario Region, Toronto, ON.

Ontario Growth Secretariat. 2009. Simcoe Area: A Strategic Vision for Growth. Ministry of Energy and Infrastructure. Queen's Printer for Ontario, Toronto, ON. 36p.

Ontario Parks. 2010. Park Visitation Data for Sibbald Point, McRae Point, Bass Lake, Mara, Springwater Provincial Parks. Ont. Min. Nat. Resour., Peterborough, ON.

Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.). 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. 976p.

Scott , D., B. Jones, C. Lemieux, G. McBoyle, B. Mills, S. Svenson and G. Wall. 2002. The vulnerability of winter recreation to climate change in Ontario's lakelands tourism region. University of Waterloo, Dept. Geogr. Publ. Ser., Waterloo, ON. Occas. Pap. 18. 84p.

Solomon, S., D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Miller, and Z. Chen. 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, Cambridge, UK. 996p.

Statistics Canada. 2007. Travel survey of residents of Canada (TSRC) – Regional profile for Simcoe County 2007. http://www.statcan.gc.ca/cgi-bin/imdb/p2SV.pl?Function=getSurvey&SDDS=3810&lang=en&db=imdb&adm=8&dis=2; accessed October 2010.

Statistics Canada. 2008. Travel survey of residents of Canada (TSRC) – Regional profile for Simcoe County 2008. http://www.statcan.gc.ca/cgi-bin/imdb/p2SV.pl?Function=getSurvey&SDDS=3810&lang=en&db=imdb&adm=8&dis=2; accessed October 2010.

9.0 Glossary

Adaptation: *Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities* (Parry et al. 2007).

Climate envelope: The distribution of the combined relationship of climate variables selected to represent a biological or physical entity such as the distribution of a tree species in relation to the combined effect of temperature and precipitation (see McKenney et al. 2010b for an example).

Climate model: *A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, and their interactions and feedback processes, and accounting for all or some of its known properties* (Parry et al. 2007).

Climate scenario: *A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined within a 'narrative storyline'* (Parry et al. 2007). Scenarios are not predictions, they are projections, and typically do not include prediction errors or likelihoods.

Vulnerability: *The degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of character, magnitude and rate of climate change and variation to which a system is exposed, [and] the sensitivity and adaptive capacity of that system* (Parry et al. 2007).

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