The Vulnerability of Winter Recreation to Climate Change in Ontario's Lakelands Tourism Region

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List of Acronyms

ATV	All-terrain vehicle
CCCma	Canadian Centre for Climate Modelling and Analysis
CCIS	Canadian Climate Impact Scenarios
CCSO	Canadian Council of Snowmobile Organizations
CGCM1	Canadian Global Coupled Model - first generation
CSC	Canadian Ski Council
CTC	Canadian Tourism Commission
DFO	Department of Fisheries and Oceans
GCM	General Circulation Model
GDP	Gross Domestic Product
GTA	Greater Toronto Area
HadCM2	Hadley Climate Model - second generation
HadCM3	Hadley Climate Model - third generation
IPCC	Intergovernmental Panel on Climate Change
ISMA	International Snowmobile Manufacturers Association
LARS-WG	Long Ashton Research Station Weather Generator
LSEMS	Lake Simcoe Environmental Management Strategy
MSC	Meteorological Service of Canada
MTO	Ministry of Transportation (Ontario)
OFSC	Ontario Federation of Snowmobile Clubs
OMNR	Ontario Ministry of Natural Resources
OMTCR	Ontario Ministry of Tourism, Culture and Recreation
OSRA	Ontario Snow Resorts Association
TGCIA	Task Group on Scenarios for Climate Impact Assessment
WTO	World Tourism Organization

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CHAPTER ONE

Introduction

At a global level, tourism had grown an average of 7.1% per year from 1950 to 1995 and now contributes approximately $609[1] billion to world trade (World Tourism Organization (WTO), 1998). According to the Canadian Tourism Commission (CTC), total tourism revenues in Canada exceeded $54 billion in 2000, supporting 546,400 jobs and contributing 4.0% to Canada's gross domestic product (GDP). Tourism's contribution to the Canadian economy now exceeds that of agriculture, forestry, mining and fisheries and is one of the largest employers, ranking fifth after retail trade, wholesale trade, business services and agricultural industries (Wall, 1998). In addition to its economic importance, tourism and outdoor recreation are also vitally important to the social needs and health betterment of Canadians.

Climate has a strong influence on the tourism and recreation sector and in some regions represents the resource on which the tourism industry is predicated. Seasons define the frequency and duration of what outdoor recreation activities can take place; climate also has a direct impact on other physical resources that are the foundation of many recreation activities (*e.g.*, water levels for boating, snow cover for skiing, breeding success of waterfowl for sport hunting). Inter-annual climate variability influences the length and quality of recreation seasons and the profitability of the tourism sector.

There is a very sharp seasonal pattern in Canadian tourism expenditures. Wilton and Wirjanto (1998) calculated that over the 1986 to 1997 period, third quarter (summer) tourism expenditures accounted for 38% of annual domestic and 62% of international tourism expenditures in Canada. Warmer temperatures also appear to have an overall positive effect on tourism expenditures in Canada. It is estimated that one degree above normal summer temperatures increases domestic tourism expenditures by $405 million (4%), and one degree above normal winter temperature decreases winter tourism expenditures marginally (Wilton and Wirjanto, 1998).

Despite the importance of climate to tourism, Smith (1993: 389) indicated that, "There have been comparatively few investigations into the relationships between climate and tourism. ... meteorologists and leisure specialists rarely communicate with each other." Consequently, the vulnerability of individual recreation industries and the tourism sector to current climate variability has not been adequately assessed.

It is perhaps not surprising then that our current understanding of how projected climate change might impact the tourism sector remains equally limited. The Recreation and Tourism Sector chapter in the Canada Country Study concluded that, "Although the implications for tourism are likely to be profound, very few researchers have begun to formulate relevant questions, let alone develop methodologies which will further understanding of the nature and magnitude of the challenges which lie ahead" (Wall, 1998: 614). Despite the significance of tourism to the Canadian economy, this sector has received far less attention by the climate change impacts research community relative to other economic sectors (*e.g.*, agriculture and forestry).

Canada's product in the international tourism marketplace is to a large extent based on its vast natural resources (oceans, coastlines, lakes, rivers, wildlife and parks) that provide an abundance of outdoor recreational opportunities. As such, Canada's tourism sector may be more sensitive to climate change than nations where cultural resources are the primary product for international tourism.

One critically important dimension of the tourism and recreation sector that will be sensitive to climate change is the length of the operating season. Any changes in season length would have considerable implications for both the short-term and long-term viability of tourism and recreation enterprises. The dominance of the summer tourism season in Canada means that an extended warm-weather recreation season is likely to be economically beneficial. The limited availability of regional studies of golfing, camping and boating reinforces this conclusion (Wall, 1998). This positive outlook must be tempered with the possibility that economic benefits may occur at the expense of increased environmental deterioration, as destinations will likely host more visitors for longer periods of time, the quality of recreation resources (*e.g.*, water quality) may decline, and increased inter-sectoral resource conflicts (*e.g.*, access to water for golf course versus agricultural irrigation, reservoir regulation for water supply) may become more pronounced.

Conversely, winter recreations, such as downhill skiing, nordic skiing, snowmobiling, ice fishing and other activities dependent on snow or ice, as well as the businesses and destination areas associated with them, are likely to be affected in a negative fashion. Some of the earliest research to examine the impact of climate change on the alpine skiing industry was completed in the Great Lakes region. McBoyle and Wall (1992), using the climate change scenarios of that period, found that the ski season to the north of the Great Lakes would be reduced by 30 to 40%. Skiing conditions would also be curtailed in the southern Georgian Bay area, resulting in the contraction (40% reduced season) or possible elimination (100% reduction) of the multi-million dollar industry. Studies of the ski season in the lower Laurentians of Quebec estimated reductions of 34 to 49% (McBoyle and Wall, 1992) and 42 to 87% (Lamothe and Periard, 1988). Similar results have been projected for ski areas in the Great Lakes area in the United States. For example, Lipski and McBoyle (1991) estimated that the ski season would be reduced by 30 to 55% in northern Michigan and 59 to 100% in southern Michigan. Using the results of a recent economic study of the skier expenditures in Michigan (Leisure Trends Group, 1995), the potential economic losses associated with a minimum projected reduction in the ski season (30%) would exceed $122 million. What happens to ski areas around the Great Lakes is crucial to the ski industry since this area is the nursery for the more challenging vacation ski resorts of North America and beyond (McBoyle and Wall, 1992).

There have been subsequent climate change impacts assessments of the ski industries in other nations (Australia - Galloway, 1988; König, 1998a and b; Austria - Breiling *et al.*, 1997; Scotland - Harrison *et al.*, 1999; Switzerland - König and Abegg, 1997), all of which project negative consequences for alpine skiing and associated businesses. Snowmaking is an integral component of the ski industry and one limitation of these studies has been the incomplete consideration of snowmaking as a climate adaptation strategy. Other important winter recreation industries, such as the estimated six billion dollar snowmobiling industry in North America (Klim, 1997), have yet to be examined.

In spite of the importance of the tourism industry, no integrated assessment of the tourism and recreation sector has been undertaken in any region of Canada (nor is one available in the international literature). The lack of systematic sector-wide assessments in major tourism regions stands as a significant barrier to our understanding of the net impact of climate change on the recreation and tourism sector and competitive relationships between tourism regions.

Research Objectives

The overall goals of the project were two-fold. First, the project sought to complete the first integrated sectoral assessment for the recreation and tourism sector. The one-year time frame for the project meant that only the winter season could be examined. Consequently, a research design to examine the four core winter recreation industries (alpine and nordic skiing, snowmobiling, and ice fishing) in the chosen study area was developed. By broadening the analysis to include the entire winter tourism sector, the project will improve our understanding of the different vulnerabilities of major winter recreation industries, the role of climate adaptation, the potential net impact of climate change in the study area, the link of climate change to regional development planning (a recognized need in the climate change literature) and the capacity of the communities to adapt to climate change. Second, the research team set out to develop new techniques for assessing climate-recreation relationships that would advance research on current climate vulnerability and the potential impacts of climate change, both in Canada and internationally. The new methodologies incorporate available recreation and climate data sources, recent transient climate change scenarios and newly available research tools (specifically the LARS-WG). The Lakelands Tourism Region of Ontario was chosen as the study area for two reasons: 1) the importance for tourism to the economy of the region, and 2) climate is a known limiting factor for winter recreation in the region. The specific research objectives were developed in part through discussions with tourism and recreation sector stakeholders and are outlined below:

1) **develop winter recreation-climate thresholds based on actual recreation data and stakeholder interviews (*e.g.*, economical snowmaking thresholds);**

   - assess the validity of climate-recreation thresholds in the published literature through comparison with observed recreation data
   - examine the sensitivity of winter recreation season simulations to the use of different climate-recreation thresholds available in the published literature
   - compile a 20-30 year historical alpine skiing season length data base for Ontario ski areas, as a potential socio-economic indicator of changing climate conditions (the Scottish skiing industry is being monitored by the British Ministry of the Environment for this purpose)
   - assess appropriate thresholds for the safe operation of ice fishing businesses

- compile data on ice cover duration and hut operator season lengths from industry stakeholders

2) examine the vulnerability of the winter tourism and recreation industry to current climate variability;

- examine how climatic sensitivities of individual winter recreation operations (alpine ski areas, ice fish hut operators) differ based on physical (*e.g.*, predominant wind direction, altitude, terrain aspect) and business variables (*e.g.*, transportation access, distance to tourism demand)

- determine the level of investment in snowmaking technology and examine its current role as an adaptation strategy (mainly for alpine ski areas, but also for nordic skiing and snowmobiling)

- examine whether the sensitivity of the alpine ski industry to climate variability changed over time as a result of investment in snowmaking

3) assess how projected climate change could affect the suitability of winter snow-pack and lake-ice conditions necessary for winter recreation activities;

- given all ski areas in the study area have implemented snowmaking technology, assess the potential impact of climate change on snowmaking capabilities (both throughout the winter and at critical periods, including early December)

- explore the implications of a diminished ice cover and reduced ice fishing activity for the fish resource and stocking requirements

4) analyze current tourism development plans in the region (some of which are known to emphasize further development of potentially vulnerable winter recreation activities) against the findings and develop recommendations for adaptive strategies.

Winter Recreation in the Lakelands Tourism Region

This section outlines the economic importance of the tourism sector worldwide, in Canada and in the Lakelands study area. The insufficient analysis of the implications of climate change for the tourism sector is problematic when the economic significance of the sector is considered. Defining the economic baseline of the recreation and tourism sector in the Lakelands Region, in part, establishes 'what's at risk' to climate change. Assessing impacts to the health and quality of life benefits associated with outdoor recreation and tourism are beyond the scope of this report.

Tourism: The Largest Economic Sector Globally

Travel and tourism provide one in every nine jobs worldwide; it is considered to be the fastest growing industry in the world (Perry, 1997). With the improved accessibility of international travel to the general public, especially during and after the 1950s, tourist activity (defined as international arrivals) had risen each year by about 7.1% from 25 million in 1950 to 563 million in 1995 (WTO, 1998). Over the same period, international tourism receipts had risen 12.4% from $2.1 billion to $611 billion (WTO, 1998). According to the WTO (1999), tourism receipts accounted for over 8% of the total world exports of goods and almost 35% of the total world exports of services. Current growth in the tourism sector is projected to continue (WTO, 1998), with tourism expected to become the largest industry in the world in the first decade of the 21st century (Perry, 1997). The WTO (1998) forecasted that by 2020 there will be 1.6 billion international tourist arrivals, spending over $3.05 trillion worldwide. These figures represent sustained average annual rates of growth of 4.3% and 6.7%, respectively. Furthermore, domestic tourism is estimated to be four to 10 times the magnitude of international tourism.

Tourism in Canada and Ontario

From 1995 to 2002, tourism has been the leading growth sector and job creator in the Canadian economy. According to the CTC (2001a), total tourism employment in Canada reached 546,400 in 2000 (Table 1.1). The 4.2% growth rate (over 1999) in the tourism sector outpaced the 3.7% rate of growth of the total business sector. From 1987 to 1997, tourism expenditures in Canada (measured in constant dollars) increased by 25.5%, almost two percentage points greater that the GDP for Canada in general (CTC, 1998). In 2000, total tourism receipts in Canada were estimated at $54.0 billion, up 7.8% from 1999 (CTC, 2001a).

Table 1.1: Recent Trends in Tourism Receipts and Employment in Canada (1998-2000)

	Employment	Receipts (billions $)
1998	518,300	46.9
1999	524,300	50.1
% change	**+1.2**	**+6.8**
2000	546,400	54.0
% change	**+4.2**	**+7.8**

Source: CTC (2000a and 2001a).

According to the WTO (1999), Canada was ranked eleventh in international arrivals in 1995 and eighth in 1998 (16.9 million arrivals and 18.8 million arrivals, respectively). During the same timeframe, Canada’s ranking for international tourism receipts rose from twelfth to ninth ($13.4 billion in 1995 and $16.9 billion in 1998) (WTO, 1999). US tourist arrivals and receipts are vital to sustaining Canada’s international tourism market. The depreciation of the Canadian dollar and enhanced marketing strategies have accelerated the number of US tourists crossing the border into Canada. Table 1.2 illustrates that since 1990, the number of US tourist arrivals has risen 21.6% and US receipts have increased by 90% (CTC, 2001b).

Domestic tourism remains many times more important both in tourist activity and economic terms. More than three-out-of-every-four arrivals in the Americas in 1995 were intra-regional (WTO, 1998) and domestic spending on tourism had risen 22% from 1991 to 1997 in Canada. Domestic spending on tourism reached $34.8 billion in Canada in 1999, up 6% or $2.08 billion from 1998 (CTC, 2000b).

Table 1.2: US Tourist Arrivals and Receipts in Canada (1990-98)

	US Arrivals (000s)	US Receipts (millions $)
1990	12,252	3,528
1991	12,003	3,642
1992	11,819	3,689
1993	12,024	4,123
1994	12,542	4,396
1995	13,005	4,799
1996	12,909	5,150
1997	13,401	5,355
1998	14,893	6,703
% change	**+21.6**	**+90.0**

Source: CTC (2001b).

Tourism in Ontario and the Lakelands Tourism Region

Ontario has the largest tourism sector in Canada, accounting for 37% of national tourism revenues and 43% of its visitors (international and domestic) (Ontario Ministry of Tourism, Culture and Recreation (OMTCR), 2001). The OMTCR (2001) estimated that approximately 106 million visitors (international and domestic) spent $16.5 billion in 1999 (ahead of mining, forestry and agriculture) and tourism was the province's fifth largest export industry, generating $7.2 billion in foreign exchange. Tourism also provided 254,000 direct jobs and an additional 172,000 indirect and induced jobs, representing over 9% of Ontario's total employment (OMTCR, 2001).

Ontarians accounted for 65% of all tourism arrivals in Ontario in 1999 and over 50% of all tourism expenditures (OMTCR, 2001). Table 1.3 identifies the number of tourist arrivals and expenditures in Ontario in 1999, by point of origin. Tourism spending trends in Ontario from 1980 to 1998 are presented in Figure 1.1. The growing importance of intra-provincial and US visitors for Ontario tourism over the last two decades is clear.

Table 1.3: Ontario's Tourist Arrivals and Expenditures (1999)

Visitors 106 million		Expenditures 16.5 billion $	
Ontario	65.7%	**Ontario**	50.9%
Other provinces	4.0%	**Other provinces**	6.2%
US	28.3%	**US**	29.8%
Overseas	2.0%	**Overseas**	13.1%

Source: OMTCR (2001).

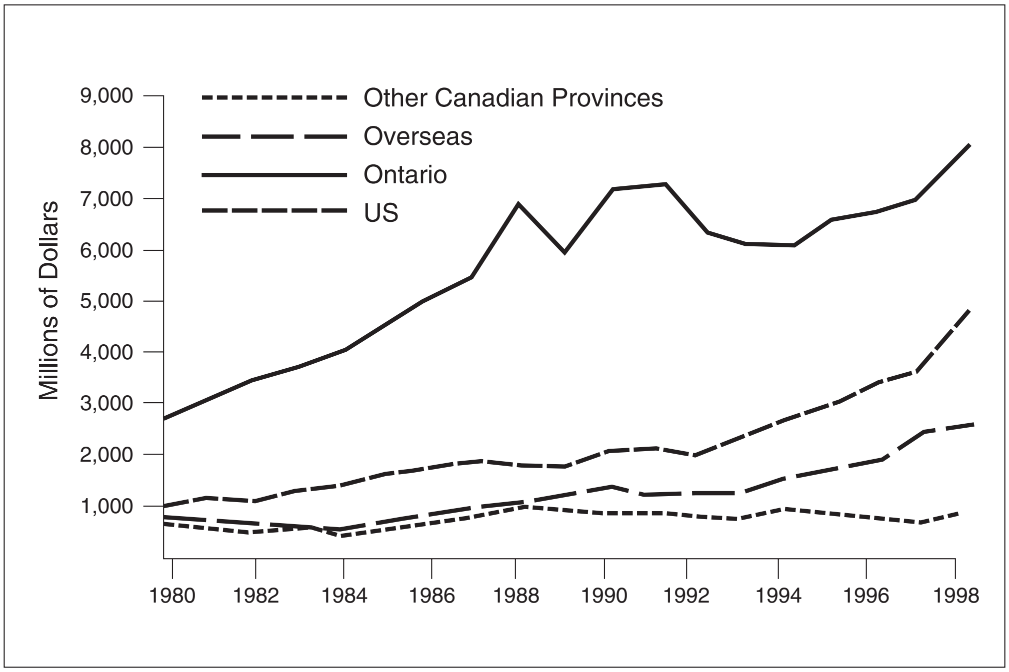


Figure 1.1: Tourism Spending in Ontario, By Origin (1980-98)
Source: OMTCR (2001).

The Lakelands Tourism Region

The Georgian Lakeland Tourism Region in southcentral Ontario (encompassing parts of the District of Muskoka and Bruce, Grey, Simcoe and Haliburton counties - Figure 1.2) was selected as the case study area because of the importance of the recreation-tourism sector to the local economy, the availability of climate and recreation data essential to the research, and because climate is a known limiting factor for winter recreation in the region. Considered Ontario's quintessential example of 'cottage country', the region is bordered by the cities of Teeswater and Orangeville to the south and Hunstville and Gravenhurst to the east. The region is a major destination within the GTA recreation-shed; tourism is a vital component of the regional economy. In 1999, the direct and indirect economic contribution of tourism was $814 million and over 26,000 full-time equivalent jobs (OMTCR, 2001). Tourism is Bruce County's second largest industry, generating $295 million in direct and indirect expenditures and employing one-in-seven of the working population (nearly 15% of the labour force) (Bruce County, 2001).

Intra-regional tourism dominates the Lakelands tourism market. Tourists from within Ontario make up the largest proportion of visitors (93% in 1999) and related expenditures. The proportion of Ontario visitors from the GTA to the Lakelands' counties is considerable and worth noting: Simcoe and Muskoka (75%), Haliburton (70%), Grey (57%), and Bruce (39%) (Statistics Canada, 1998a). The depreciation of the Canadian dollar also appears to have had a positive effect on the Region's tourism industry in the late 1990s, with US arrivals and expenditures increasing 78% and 143%, respectively (Table 1.4).

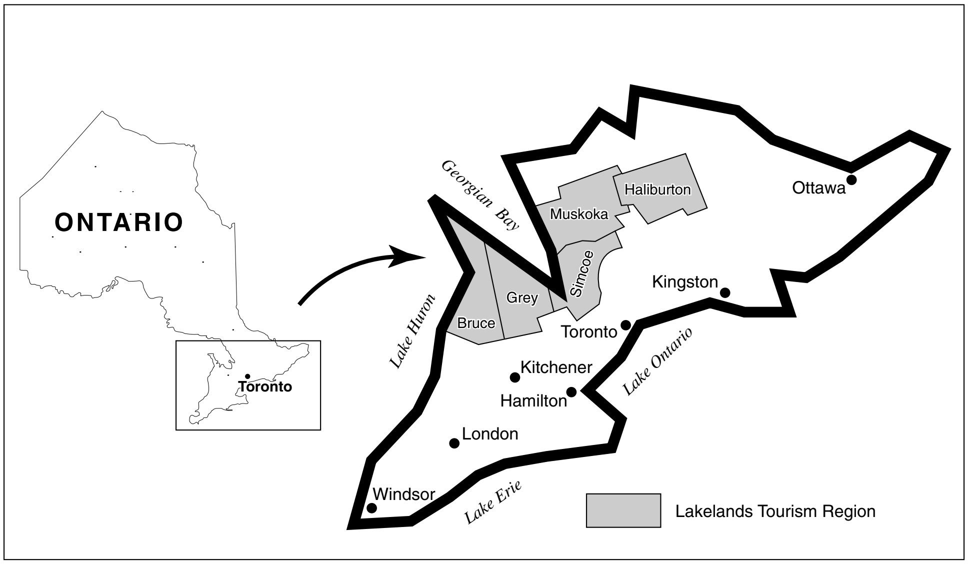


Figure 1.2: Lakelands Tourism Region Study Area

Table 1.4: Lakelands Tourism Arrivals and Expenditures by Origin (1996 to 1999)

	Ontario	Other Province	US	Overseas	TOTAL
1996 (a & b)					
Arrivals (000s)	9,005	60	268	119	9,452
Expenditures (millions)	$625.9	$12.5	$47.2	$41.0	$726.6
1998 (c & d)					
Arrivals (000s)	9,346	99	361	146	9,952
Expenditures (millions)	$734.7	$17.1	$91.0	$42.9	$885.7
1999 (e & f)					
Arrivals (000s)	10,290	110	478	223	11,101
Expenditures (millions)	$811.3	$34.2	$114.7	$59.8	$1,020.0
% of change since 1996					
Arrivals	**14.3%**	**83.3%**	**78.4%**	**87.4%**	**17.4%**
Expenditures	**29.6%**	**173.6%**	**143%**	**45.9%**	**40.4%**

Source: a) Statistics Canada (1996a), b) Statistics Canada (1996b), c) Statistics Canada (1998a), d) Statistics Canada (1998b), e) Statistics Canada (1999a), f) Statistics Canada (1999b)

Tourism in the Lakelands Region is mainly driven by Ontario residents seeking outdoor recreation experiences. Statistics Canada's travel surveys provide information on pre-specified activities that visitors might engage in during their trip. This activity participation is not specific to a particular location, but indicates the types of activities enjoyed in the counties that make up the Lakelands Region. According to the travel survey (Statistics Canada, 1998a), 47% of all persons visiting the Lakelands Region participated in some type of outdoor recreation activity.

The participation numbers for specific outdoor recreation activities in the Lakelands Region (Table 1.5) show the dominance of warm-weather activities. Nonetheless, there has been a growing recognition of the importance of winter recreation activities (such as alpine skiing, snowmobiling, nordic skiing and ice fishing) on the sustainability of the Lakelands' economy. The importance of each of these four major winter recreation activities is discussed in greater detail below.

The net economic activity and employment generated by the winter recreation sector, in part, represents what is potentially at risk to climate change in this region. However, many businesses could not survive on one season of activities alone, so the availability of a supplementary income in winter is crucial to their existence.

Table 1.5: Participation in Outdoor Recreation Activities While Visiting Lakelands Counties (1999)

	(‘000s)			
	Canadian	**US**	**Overseas**	**TOTAL**
Outdoor Activities	4,342	180	93	4,615
Hunting & Fishing[1,4]	642	897	11	1,550
Nordic Skiing[2]	46	2	0	48
Alpine Skiing[2]	354	26	4	384
Snowmobiling[2]	75			75
Swimming[3]	2,529	100	66	2,695
Other Water-based Activities[3]	1,378	54	25	1,457

1 winter and summer activities
2 winter activities
3 summer activities
4 includes ice fishing
Source: Statistics Canada (1999a and 1999b)

The Winter Recreation Resource

Alpine and Nordic Skiing

Canada’s alpine ski industry experienced significant growth from 1985 to 1995. In 1995, there were 252 alpine ski areas operating across Canada, 28% more than were operating in 1985. Total revenues of alpine ski area operations increased 68% over the same decade, to over $441 million in 1995 (Statistics Canada, 1996c and 1996d).

Following the recession of the 1980s, the total number of active[2] alpine skiers grew annually and peaked in 1988 at 2.1 million (Canadian Ski Council (CSC), 2000). In spite of the strong economic growth at ski areas, the total number of skiers has decreased over the past decade. According to the 1999/2000 Canadian Skier and Snowboarder Survey (CSC, 2000), the total number of active alpine skiers declined to less than 1.5 million during the 1999/2000 season.

Regionally, Ontario hosts 30% (430,000 skiers) of Canada’s active alpine skiers, second only to Québec, which hosts 31%, or 440,000 of Canada’s active alpine skiers (CSC, 2000). According to the CTC (2000c), Ontario’s alpine ski areas sold over 2.7 million lift tickets during the 1999/2000 season, down slightly from 2.8 million in 1998/99. For the year 2000/01, the OSRA reported 3.2 million skier visits in Ontario (Minardi, 2001).

Ontario residents represented the largest proportion of skiers at Ontario alpine ski areas (81%) but contributed only 37% of the expenditures related to the industry (Table 1.6). Despite Ontario’s large share of active alpine skiers, Ontario’s alpine equipment sales were well below the national average (with the largest loss of national share 1.2%) (CSC, 2000). The CSC (2000) reports that alpine ski sales increased 9.1% from the 1997/98 season to the 1999/2000 season (or 9.4 million in 1997/98 to nearly 12 million in 1999/2000).

Table 1.6: Number of Visitors and Expenditures Related to Alpine and Nordic Skiing in Ontario (1999)

('000s)	Ontario	Other Provinces	US	Overseas	TOTAL
Alpine Skiing					
Number of visitors	464	8	62	36	570
Expenditures ($)	$34,959	$4,011	$14,641	$39,171	$92,782
Nordic Skiing					
Number of visitors	126	20	21	16	183
Expenditures ($)	$10,486	$4,651	$6,664	$12,284	$34,085

Source: OMTCR (2001)

Winter-related recreational activities such as skiing are a primary reason for a large proportion of the domestic travel in Canada. For example, Toronto is home to approximately 11% (156,000) of Canada's active alpine skiers (CSC, 2000). Furthermore, the CSC reports that 45% of eastern Canadians travel less than one hour to their ski area destination (CSC, 2000).

The Lakelands Region contains over half of the 40 alpine ski resorts registered with the OSRA. While the importance of the alpine ski industry to the communities in the Lakelands Region is well known to planners and tourism officials, no systematic economic impact analysis has been completed in the last 10 years (Minardi, 2000).

The alpine ski industry in the Lakelands Region has continued to grow over the past 15 years. Table 1.7 synthesizes improvements made since 1986 with regards to snowmaking and terrain enhancement; on average, $25 million is spent annually in Ontario on resort upgrades (MacDonald, 1988; Lebrecht, 1994). Among the enhancements has been the regular investment in high capacity snow guns that often double and triple snowmaking capacities of individual resorts, computerized snowmaking operations and the construction of privately owned water retention plants for snowmaking. Blue Mountain Resort has even constructed a pipeline to Georgian Bay to safeguard its capacity to produce snow. In the late 1980s, a number of ski areas integrated the newest advancement in technology into their snowmaking operations - Snowmax. A protein-based chemical, Snowmax is added to water under pressure and allows snow to be created at temperatures above freezing to a maximum of 5° Celsius (MacDonald, 1989). One anecdotal piece of evidence of the growth of the alpine ski industry since the late 1980s and its current importance to Lakelands' communities is the self-reported $10 million payroll of Blue Mountain resort in 2001 (Blue Mountain Resort, 2001).

Nordic skiing in Ontario has only about one-third as many participants as alpine skiing and generates about 36% of the expenditures of alpine skiing. Although Ontario has the second largest share of Canada's Nordic skiing market (30.6%, second to Québec which has 32.1%), Ontario's nordic ski retail sales trends from the 1989/90 to the 1992/93 seasons illustrate a loss of approximately 7% (slightly higher than the national average, a reduction of 4.2%). In 1990/91, Nordic ski sales reached $1.9 million whereas the 1992/93 season generated $1.77 million in sales.

There are four OSRA Nordic ski trails areas in the Lakelands Region, with a number of the alpine ski resorts also offering Nordic trails. In addition, there are a large number of 'blaze your own trails' Nordic ski areas located in parks and conservation areas. Because of this, it is hard to quan-

Table 1.7: Lakelands Region Alpine Ski Area Investments (1986-2000)

	Improvements undertaken (during off-season)									
Resort	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1994**	**1995**	**2000**
Horseshoe			**$2,000,000** ↑ s.m. capacity	**$1,500,000** ↑ s.m. capacity add a chair lift renovate chalet facilities	**$2,000,000** add a s.m. plant improve trails new hill lights add a chair lift	↑ runs improve hills ↑ s.m. capacity				**$1,000,000** build tunnel to connect two main ski areas
Talisman	**$1,000,000** add a chair lift build lodge ↑ triple s.m. capacity		**$200,000** ↑ s.m. capacity ↑ rental equipment availability	**$1,250,000** renovate hotel new grooming equipment introduce Snowmax		**$1,500,000** add chair lift (quad)	**$500,000** build a new clubhouse ↑ trails add skating rinks	**$450,000** ↑ s.m. capacity add chair lift (double)	**$400,000** ↑ s.m. capacity add kids adventure centre	**$200,000** ↑ s.m. capacity
Blue Mountain	↑ trails renovate inn begin condo development near slopes	**$600,000**	**$2,500,000** add chair lifts new grooming equipment	**$2,500,000** add a chair lift (quad) new grooming equipment introduce Snowmax	**$1,250,000** ↑ trails add a chair lift (double) add a s.b. run	↑ s.m. capacity	**$3,000,000** ↑ night lighting ↑ s.m. capacity (80 tower snow guns)	**$2,300,000** extend chair lifts build pipeline to Georgian Bay to ↑ s.m. capacity	↑ s.b. runs	**$3,250,000** add chair lifts ↑ s.m. capacity
Snow Valley			**$100,000** add a chair lift renovate chalet	**$400,000** ↑ s.m. capacity add s.b. run	↑ s.m. capacity ↑ runs ↑ hill lighting	↑ s.m. capacity		add a chair lift build new clubhouse	add chair lifts ↑ s.b. runs	
Hidden Valley			**$750,000** add a chair lift (quad) ↑ s.m. capacity expand chalet	**$750,000** renovate chalet reshape runs	**$55,000** ↑ s.m. capacity upgrade rental shop	↑ s.m. capacity	↑ s.m. capacity ↑ night lighting	↑ s.m. capacity	↑ ski runs ↑ night lighting	
Glen Eden	**$1,150,000** computerize ticket/registration system ↑ s.m. capacity			**$1,500,000** computerize s.m. system new grooming equipment		↑ s.m. capacity	**$245,000** new grooming equipment	↑ s.m. capacity ↑ night lighting	**$100,000** ↑ s.m. capacity ↑ night lighting	**$2,500,000** add chair lift (quad) build new lodge
St. Louis Moonstone	↑ lift capacity ↑ s.m. capacity ↑ height of mountain		**$1,000,000** ↑ s.m. capacity computerize s.m. system	introduce Snowmax add chair lifts (quad)	**$1,000,000** ↑ s.m. capacity ↑ X-country trails	**$1,100,000** ↑ s.m. capacity upgrade chalet add a chair lift (triple)	↑ s.m. capacity by 50% add a chair lift ↑ beginner runs		**$425,000** ↑ s.b. rentals build s.m. plant	↑ s.b. rentals

Legend: s.m. - snowmaking; s.b. - snowboarding

Sources: Skol (1986 and 1989); MacDonald (1988); Mayers (1988); Curson (1990, 1991 and 1992); Lebrecht (1994 and 1995); Knowles (2000) tify the exact number of Nordic skiers and the revenues that these skiers generate. Nonetheless, the OMTCR (2001) estimated that the nordic ski industry generated approximately $35 million in Ontario in 1999 (Table 1.6).

Snowmobiling

The Canadian Council of Snowmobile Organizations (CCSO) (2000) estimates that the snowmobile industry generates over $3.1 billion in economic activity annually at the national level. Importantly, much of this contribution comes in the winter, when the tourism industry needs increased business to stabilize employment levels in the industry. Figure 1.3 illustrates the steady growth in actual members, trail permits, and kilometres of groomed trails in Canada over the last 11 years.

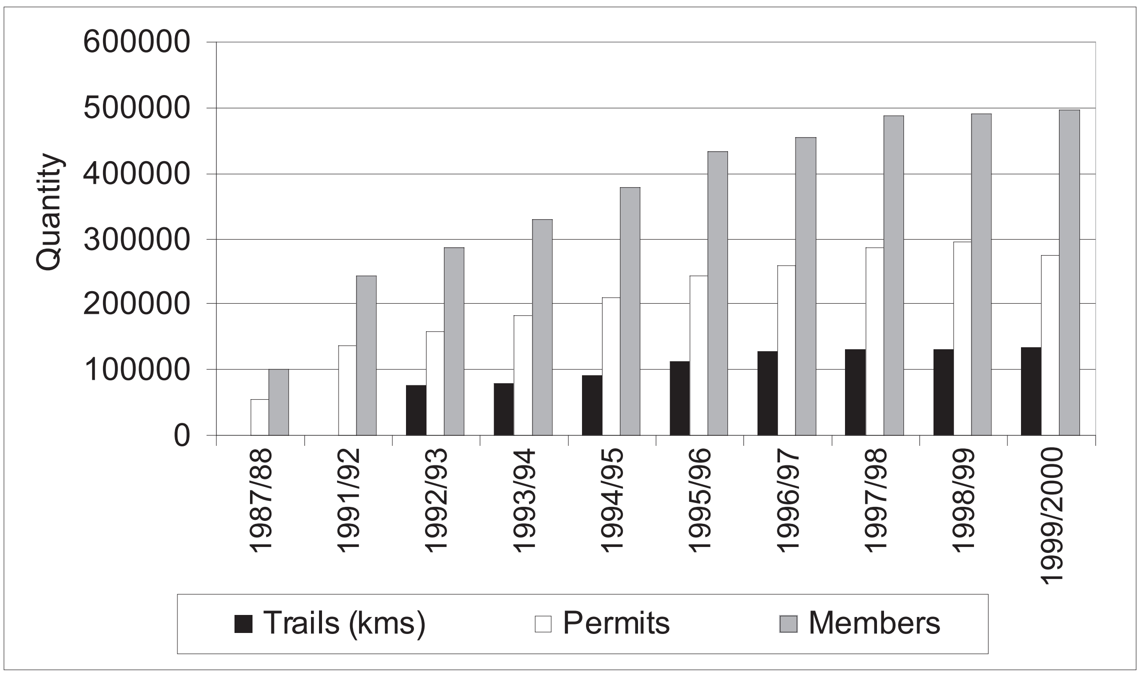


Figure 1.3: Growth in Permit Holders, Members and Trails in Canada (1987/88 - 1999/2000)
Source: CCSO (2000)

Both the CTC and the Province of Ontario invested substantially in promoting snowmobiling in Ontario in 1998/99, reaffirming it as a key generator of economic growth, employment and tourism revenue. In 2000 and 2001, the Ontario Federation of Snowmobile Clubs (OFSC) received $20 million from the Northern Ontario Heritage Fund for trail development and enhancement in northern Ontario.

The Ontario Ministry of Transportation issued approximately 225,000 snowmobile vehicle permits in 1999 (Ontario Ministry of Transportation (MTO), 1999) and the province attracted approximately 25,000 snowmobiling tourists (Government of Ontario, 2000). The OFSC, a non-profit organization composed of 281 local snowmobile clubs and their associations, provides access to 49,000 kilometres of groomed snowmobile trails through a user-pay system. Sales of trail permits grew to 130,207 in 2001 (Figure 1.4), representing over $12.5 million in direct sales revenues. The OFSC also estimated that at least 20,000 snowmobilers access the trail system annually without purchasing a trail permit (OFSC, 2000). A 1991 study (Eagles *et al.*, 1991) found that Ontario snowmobilers used their snowmobile on average 35.6 days per season.

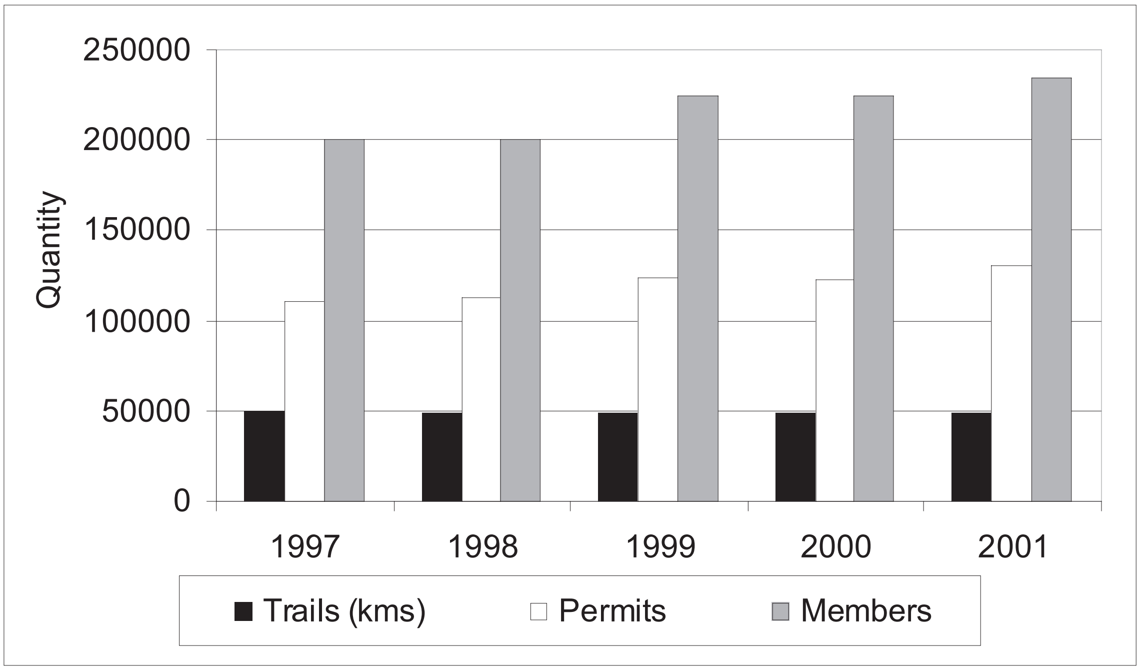


Figure 1.4: Growth in Permit Holders, Members and Trails in Ontario (1997- 2001)
Source: OFSC (2001)

In terms of economic impact, the OFSC estimated that the organized recreational snowmobiling on its trail system now contributes nearly $1 billion annually to the provincial economy (OFSC, 2000). The OFSC does not provide any details about the methodology used to calculate this estimate. If the estimated number of snowmobile days in Ontario (4.6 million - derived from Eagles *et al.*, 1991 and OFSC, 2001) and Michigan (2.4 million - Stynes *et al.*, 1998) are considered, the estimated economic impact per snowmobile day is comparable ($217.4 in Ontario and $211.3 in Michigan).

The number of snowmobilers and their associated economic impact in the Lakelands Region is considerable and growing. Data on snowmobiling activity, based on their snowmobiling districts, are available from the OFSC. There are 16 OFSC districts in Ontario; four districts cover the Lakelands study area (Figure 1.5). There are over 9,100 kilometres of trails in these four districts, representing 19% of OFSC trails province-wide. During the 1993/94 snowmobiling season, 16,186 trail permits were sold within these four districts (OFSC, 1994); in 1998/99, the number more than doubled to 36,770, representing approximately 30% of all trail permits sold in 1998/99 in Ontario. Taking the regular price of an OFSC trail permit at $150 (OFSC, 2000), the snowmobile associations within Lakelands Region generated $5.5 million in permit sales alone.

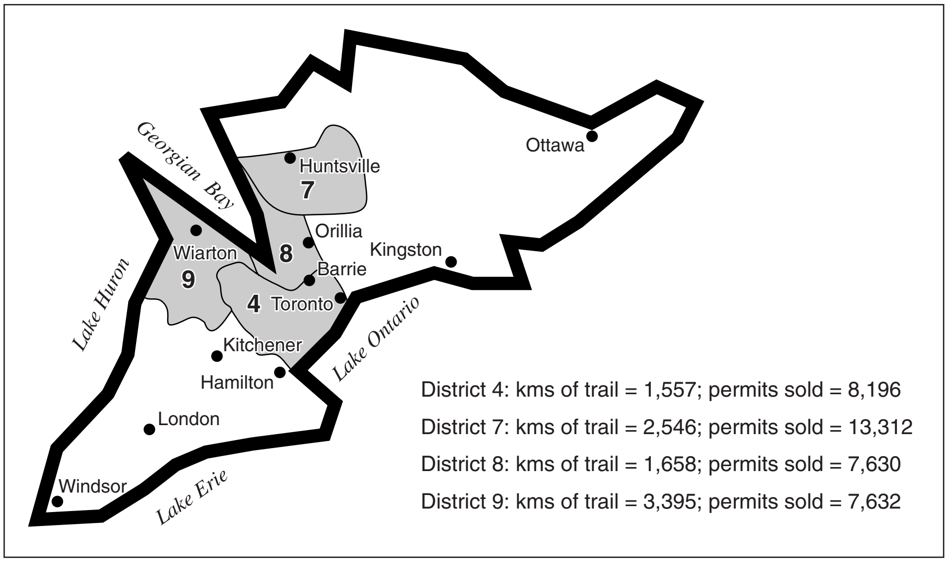


Figure 1.5: OFSC Districts in the Lakelands Region Study Area, 2000
Source: OFSC (2000)

Ice Fishing

In 1995, anglers in Canada spent $2.5 billion on goods and services related to their fishing activities (Department of Fisheries and Oceans (DFO), 1997). Resident anglers spent $1.75 billion or $533.00 per angler, and foreign non-residents spent $655.7 million or $875.00 per angler. Ontario residents accounted for 33.1% of all expenditures by resident anglers and foreign non-residents spent 65.5% of their direct expenditures in Ontario (DFO, 1997).

Angling time in Ontario was 23,436,102 angler days[3] in 1995 (DFO, 1997). The number of days fished through the ice was 2,693,245 or 11.5%. If fishing-related expenditures approximate the proportion of angling activity, ice fishing may be estimated to have contributed $118 million in direct expenditures to the Ontario economy in 1995 (DFO, 1997).

In the Lakelands Region in 1998, it was estimated that that there were 862,000 domestic person visits where people engaged in recreational fishing out of a provincial total of 3,225,000 person visits where fishing was undertaken. The most heavily winter-fished lake in Ontario is Lake Simcoe (OMTCR, 1999). Located 100 kilometres north of Toronto, in the southcentral part of the Lakelands Region, some 30 commercial ice hut companies operate on Lake Simcoe. The scale of these operations varies from one to over 30 huts. Some of the operations are stand-on-their-own operations; the majority of yearly income is derived from renting ice huts. Other operators, pejoratively referred to as 'fly by nighters', are simply looking for a way to make a little extra money. These operations typically advertise their personal hut in a Toronto newspaper, neglect to carry liability insurance, and provide limited service. Other operations are more diversified. Marinas and sporting goods stores are examples of these operations, where ice fishing is simply an extension of summer operations focused on boating or fishing. Generally, the income generated from diversified operations is a small percentage of their annual income.

The Lake Simcoe ice fishery is a valuable asset to the Lakelands Region. In 1995, it generated approximately $28 million in recreation-related expenditures (Lake Simcoe Environmental Management Strategy (LSEMS), 1995). While the west side of Lake Simcoe is fairly diversified in terms of its economy, the smaller towns on the east side of Lake Simcoe, where most hut operators conduct business, are substantially more dependent on the tourist revenue that ice fishing generates in winter.

The winter fishery has important implications for stocking and management of fish species, as catch rates are substantially higher than in other seasons. Creel surveys from Colpoys Bay and Owen Sound in the Lakelands Tourism Region demonstrate quite dramatically the impact of ice fishing on fish stocks. In one 48-day winter creel survey in 1994, it was estimated that 8,932 fish were taken from Colpoys Bay and Owen Sound (Mohr, 1998a). In comparison, only 2,559 fish were taken during a 62-day summer creel survey in the same area in 1996 (Mohr, 1998b). For some species, two months of ice fishing can remove the same number of fish as six months of summer fishing (Reed, 2001).

Summary

It has been established that the Lakelands is one of Ontario's most important tourism regions, whether measured in levels of activity or expenditures. Tourism is fundamental to the Region's economy. While summer has been and continues to be the peak season, winter activities are of considerable importance and are receiving more attention as the Region strives to reduce seasonality and build a year-round tourism industry. Climate and weather are fundamental to both the quantity and quality of both summer and, especially, winter activities. It follows that the Region and, by extension, the province have a great deal at stake from any modifications in climate.

CHAPTER TWO

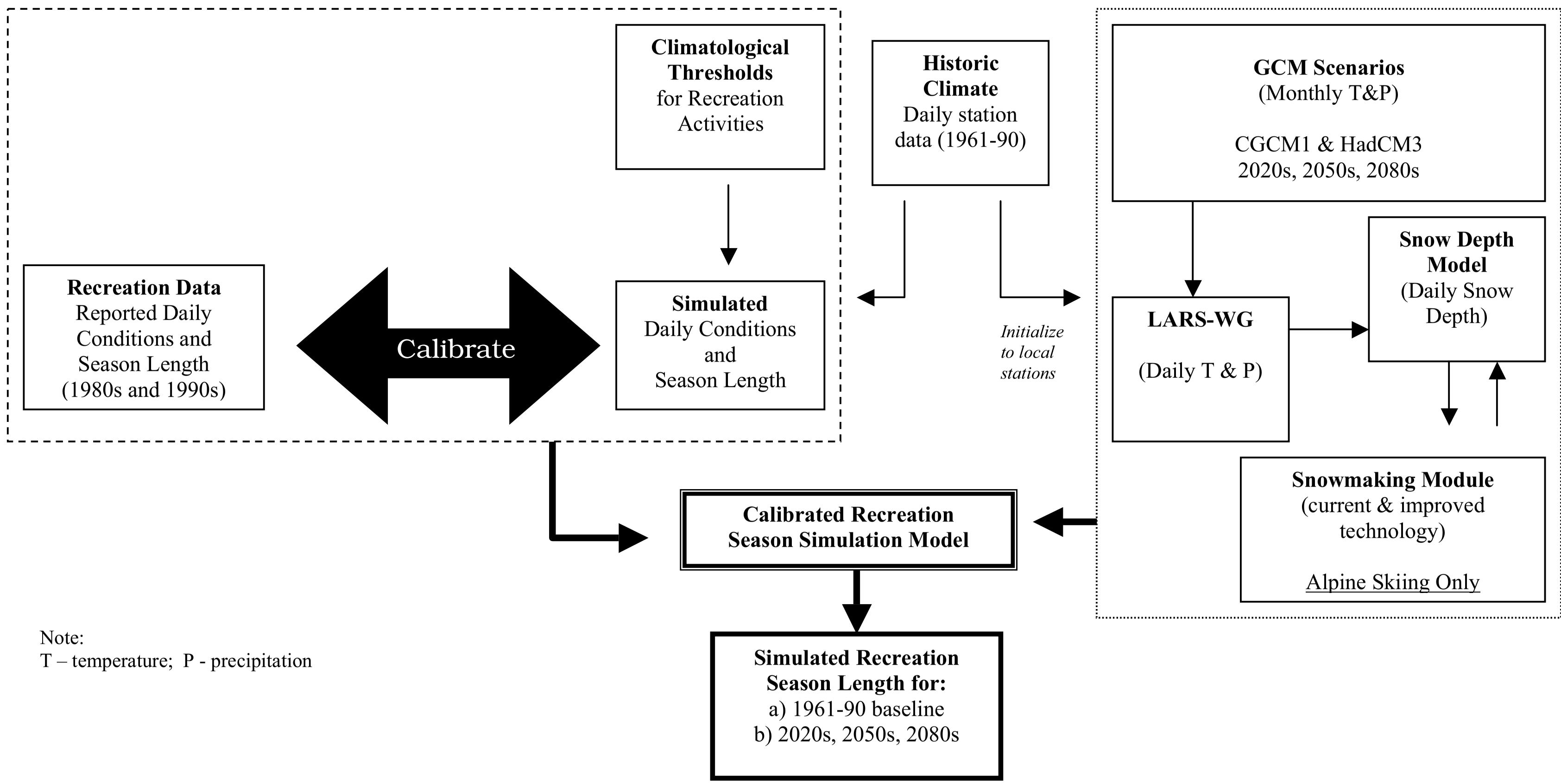
Climate Change Impact Methodology

The nature of the physical resource (*i.e.*, snow or ice cover) that defines the climatic sensitivity of the four major winter recreation industries (alpine skiing, Nordic skiing, snowmobiling, ice fishing) included in this study, required the development of two distinct research designs: one to assess the climate sensitivity of alpine skiing and the trails-based activities of nordic skiing and snowmobiling, and a second for ice fishing.

Research Design for Alpine Skiing, Nordic Skiing and Snowmobiling

The methodological framework for the three snow-based recreation activities was almost identical and is outlined in Figure 2.1. The only difference was that snowmaking capacity had to be incorporated into the alpine skiing analysis (see the climate change scenarios box in Figure 2.1). The first stage in the method was construction of the historical climate data set (daily) for each of the seven climate stations selected. These data were used to calibrate the climate-recreation simulation model and parameterize the Long Ashton Research Station Weather Generator (LARS-WG) to local climate stations. The second stage was to calibrate the recreation season simulation model with observed recreation data. Initially, thresholds in the literature were used to define suitable climatic conditions for the three types of recreation (*e.g.*, a skiable day). After comparing these thresholds against observed recreation data, it was determined that the alpine skiing thresholds performed unsatisfactorily in the study area. A revised set of climate thresholds was developed through discussions with ski industry stakeholders and analysis of the climate data. The climate thresholds for nordic skiing and snowmobiling performed adequately and were used in the analysis. After calibrating the recreation season model with observed recreation data, recreation seasons were simulated for the 1961-90 period.

The climate change scenarios were constructed in three stages. Monthly climate change scenarios from two General Circulation Models (GCMs) (Canadian Global Coupled Model - first generation (CGCM1) and Hadley Climate Model - third generation (HadCM3)) were obtained for the 2020s, 2050s and 2080s. These scenarios were temporally downscaled with the LARS-WG to produce daily temperature and precipitation values for each of the above time periods. The temperature and precipitation data were then used as inputs into a snow cover model that had been parameterized to the climate stations in the study area. A snowmaking module was integrated with the snow cover model at the locations of the five alpine ski areas included in the study. The technical capacities and decision rules for the snowmaking module were developed through communication with ski industry stakeholders. The recreation season simulation model was then applied to the climate change scenarios to project recreation season lengths in the 2020s, 2050s and 2080s. Each of the methodological stages is described in greater detail below.



Note:
T – temperature; P - precipitation

Figure 2.1: Methodological Framework for Alpine Skiing, Nordic Skiing and Snowmobiling Climate Change Impact Assessment

Historical Climate Data Construction

The climate stations selected for this study were based on three criteria:

1) proximity to major recreation resources (large ski resorts, snowmobile trail networks);
2) broad spatial coverage of the study area;
3) length of record and data quality.

Table 2.1 identifies the climate stations used in this study and the nearby recreational resources they represent. Daily temperature (maximum, minimum and mean) and precipitation (rain and snowfall) were obtained from the 1999 regional daily climate data set available from the Meteorological Service of Canada, Environment Canada (MSC, 1999a). Daily snow depth data were obtained from the Climate Research Branch of the Meteorological Service of Canada, Environment Canada (MSC, 2000). Snow depth observations at climate stations are typically collected in open field conditions and thus underestimate snow depth in protected and forested areas. Regardless, they are pertinent to an analysis of winter recreation trails as open field conditions are representative of the first areas of recreation trails to lose snow cover (*i.e.*, the weakest link of the trail system, that would result in its closure). In all cases, a complete record for 1961 to 1996 (the last year for which rehabilitated snow depth data were available) was sought. The lower portion of Table 2.1 summarizes how missing data were addressed for each station.

Table 2.1: Selected Climate Stations

Climate Station	Lat.	Long.	Elevation (masl)	Temp.-Precip. Data	Snow Depth Record	Nearby Alpine Ski Areas	OFSC Snowmobile District
Haliburton	45.00	78.35	320	1965-92	1961-92	Sir Sam's	6 Haliburton
Huntsville	45.20	79.13	286	1961-99	1961-96	Hidden Valley	7 Huntsville
Muskoka [1]	44.58	79.18	282	1961-99	1961-96		7 Gravenhurst
Orillia	44.37	79.25	220	1961-99	1961-96[b]	Horseshoe	8 Orillia West
Collingwood-Thornbury	44.29	80.13	221	1961-99[a]	1961-96[c]	Blue Mountain	8 Collingwood
Chatsworth	44.24	80.54	305	1961-99	1961-96	Talisman	9 Owen Sound
Wiarton [1]	44.45	81.06	222	1961-99	1961-96		9 Wiarton

[1]indicates Environment Canada primary climate station

a) Collingwood (Stn 6111793): Mar. 1960 -Nov. 1964; Owen Sound (Stn 6116132): Dec. 1964 - Dec. 1999

b) Stations used as a substitute for Tmax and Tmin
Coldwater (Stn 6111769): Aug. 1971 - May 1977; Washageo (Stn 6111325): Jun. 1968 - Nov. 1970;
Dalrymple (Stn 6111965): Dec. 1970 - Jul. 1971; Big Chute (Stn 6110731): Jan. 1962 - May 1968, and Nov. 1968 - Jan. 1969

c) Collingwood (Stn 6111793): Mar. 1960 -Nov. 1964; Owen Sound (Stn 6116132): Dec. 1964 - Dec.1999

Climate Change Scenario Construction

General Circulation Model (GCM) Scenarios

The climate change scenarios used in this analysis were obtained from the CCIS project. The scenarios provided by Canadian Climate Impact Scenarios (CCIS) (2001) have been constructed using recognized methodologies and in accordance with the recommendations of the Intergovernmental Panel on Climate Change (IPCC's) Task Group on Scenarios for Climate Impact Assessment (TGCIA). The impacts community established the TGCIA to promote consistency in the use of climate change scenarios, in order to facilitate both national and international assessments of the impacts of climate change and climate variability and their comparability. TGCIA has outlined a number of criteria to which GCMs should conform if they are to be used in the construction of climate change scenarios.

The scenarios available from CCIS are derived from climate change experiments undertaken at six international climate-modelling centres that meet the criteria established by TGCIA. The scenarios are derived from 30-year means (2010-39 corresponding to the 2020s scenario, 2040-69 to the 2050s scenario and 2070-99 to the 2080s scenario), and represent change with respect to the 1961-90 baseline period. Data from the six modelling centres were obtained for the area 43-46ºN by 79-82ºW, which would incorporate between four to six grid boxes depending on the GCM. The IS92a greenhouse gas plus aerosol ensemble scenarios (gax) were used when ensembles were available (CGCM1, HadCM2 and HadCM3) and IS92a greenhouse gas plus aerosol runs for the other scenarios. A comparison of the magnitude of change in mean annual temperature and precipitation projected by the GCM scenarios for each of the three time periods is presented in Figure 2.2.

The CCIS Project promotes the use of scenarios derived from the climate modelling experiments undertaken by Canadian Centre for Climate Modelling and Analysis (CCCma), but also stresses that impacts' researchers should consider for the probable range of future climates rather than relying on any single scenario. In order to consider the range of climate projections for the area of study, the CGCM1 scenario from the Canadian Centre for Climate Modelling and Analysis and the HadCM3 scenario from the United Kingdom's Hadley Centre were selected for this study. Although the HadCM2 scenario represents the lower bound of temperature change in the study area, the HadCM3 scenario was selected because of improvements incorporated in the newer model. Although the Great Lakes Regional Assessment Team (2000) of the US National Assessment of the Potential Consequences of Climate Variability and Change suggested that lake effect snowfall would diminish in the lower Great Lakes region under both the CGCM1 and HadCM2 scenarios, changes in climate variability and storm patterns were not considered in this analysis.

Temporal Downscaling with the LARS-WG

LARS-WG is a stochastic weather generator that can be used to simulate a suite of climate variables for a given time-series at a single site (Semenov *et al.*, 1998). Stochastic weather generators are not predictive tools for use in weather forecasting, but are a means of generating a time-series of synthetic weather with statistical properties that are not significantly different to the observed climate station data used to parameterize the model. Stochastic weather generators can

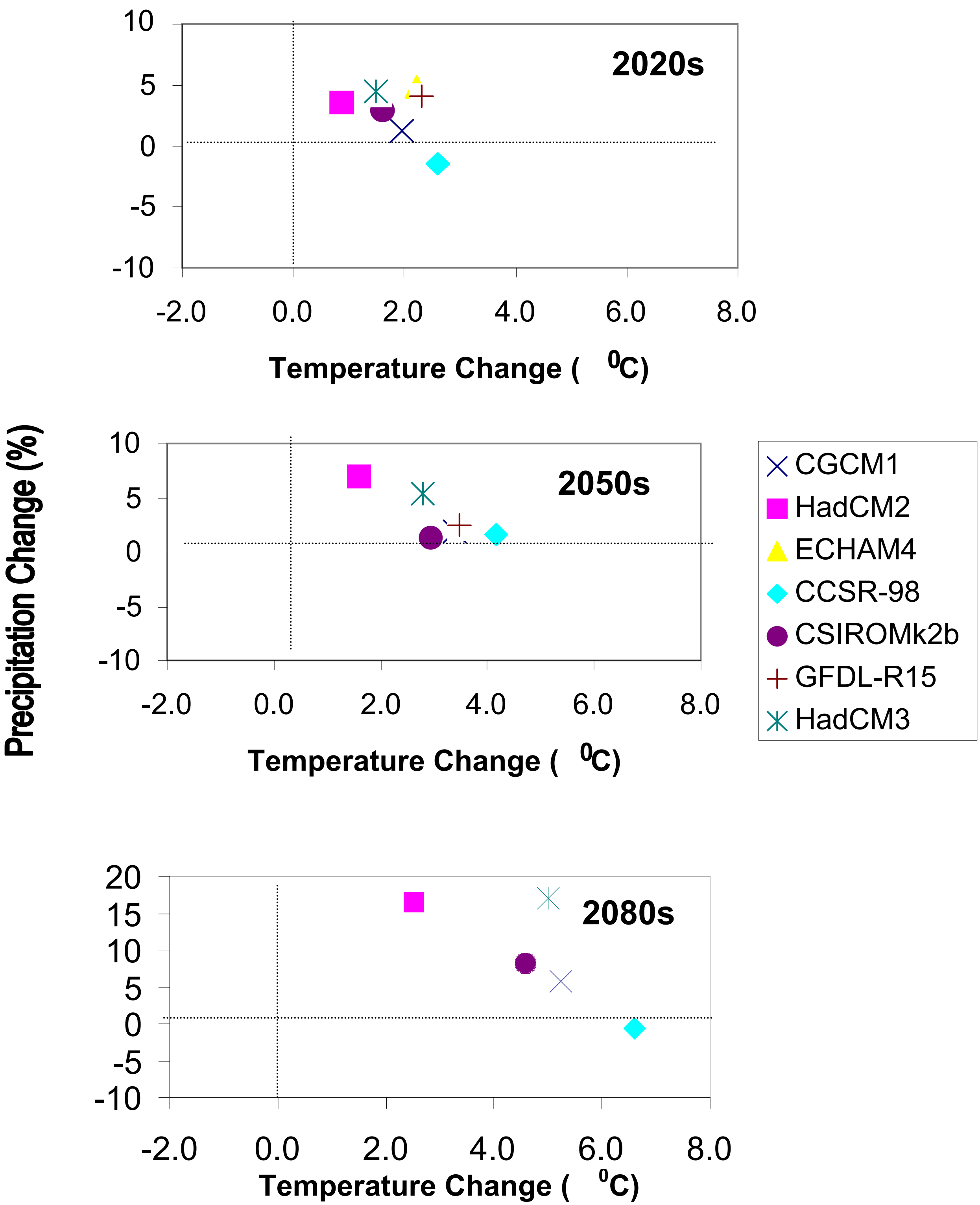


Figure 2.2: GCM Comparison: Projected Annual Climate Change in Southern Ontario (with respect to 1961-90)

serve as an inexpensive computational tool to produce site-specific multiple-year climate change scenarios at the daily time scale, which incorporate changes in mean climate and climate variability as projected by coarse scale GCMs (Semenov and Barrow, 1997). The synthetic weather generated by LARS-WG is random and so repeated runs with different random speeds will give different weather sequences. The longer the time period of simulated weather that is used, the more it will cover the full range of possible weather events. Unlike some weather generators that use predefined distributions, the LARS-WG uses empirical distributions based on every single observation provided from the station record, and thus should produce better simulations of precipitation and wet/dry periods. Dr. Mikhail Semenov of the University of Bristol made LARS-WG version 3.1 (Windows 9x/NT/2000) available for this study.

The procedure for generating synthetic weather with LARS-WG involved several stages. Daily climate data (consisting of minimum and maximum temperature and precipitation) from MSC (1999a) were extracted and processed into the format required by LARS-WG. The baseline time-series used to parameterize LARS-WG for each of the seven climate stations listed in Table 2.1 was 1961-90. These observed weather data for the chosen stations are used to parameterize LARS-WG and derive the site-specific statistics required to generate the synthetic weather. At this stage the Q-Test function was run to examine the validity of using LARS-WG in the study area. The Q-Test function compares the statistical distributions of the temperature and precipitation variables produced by LARS-WG with those of the observed data (*i.e.*, the quarterly probability distributions for length of wet series, length of dry series, length of frost series, length of hot series - days with maximum temperature greater than 30˚C, and monthly probability distributions for precipitation) (Semenov and Barrow, 2000). Examination of Q-Test results at each of the seven climate stations used in this analysis revealed no systematic significant differences between the synthetic and observed weather data.

With the weather generator parameterized to the local climate stations, the next stage consisted of developing the climate change scenarios that would be used by LARS-WG to generate synthetic weather for future time-series. Monthly mean temperature and precipitation change values from the CGCM1 and HadCM3 models were used to develop climate change scenarios for the 2020s, 2050s and 2080s. Each of the parameterized station files was then run with the six climate change scenarios (three time-series for each of the two CGMSs used). The same random number seed was used in each run to ensure consistency among stations. When completed, the daily temperature and precipitation data set for each climate station included 1961-90 (observed) and 2010-99 (simulated).

Snow Cover Model

A variety of hydrological and agriculturally-based snow cover simulation models, ranging from simple empirically-derived equations to complex physically-based models operating at hourly or finer timesteps (*e.g.*, Cazorzi and Fontanna, 1996; Kuchment and Gelfan, 1996; Semádeni-Davies, 1997; Dunn and Colohan, 1999; Schroeter *et al.*, 1999; Kongoli and Bland, 2000), are documented in the literature to estimate daily depth of snow cover. The more sophisticated models incorporate physical processes of the following: precipitation (snowfall); snow accumulation, density, distribution (drifting) and compaction; movement of rainfall and meltwater through the snowpack; ablation and condensation; and the energy balance of the snowpack and associated micro-climatic factors (*e.g.*, slope, aspect, elevation, land cover/vegetation).

Given the data limitations associated with atmospheric variables available from the National Climate Archive[4] and Canadian and UK global climate models, a simple approach to estimate snow cover was adopted. Based largely on methods used to develop the *Canadian Daily Snow Depth Database* (Brown and Braaten, 1999) and *Water Balance Tabulations for Canadian Climate Stations* (Johnstone and Louie, 1983), the technique involved estimating three parameters: 1) amount of precipitation that falls as snow and rain; 2) snow accumulation; and, 3) snowmelt.

Johnstone and Louie (1983) estimated snowfall from total precipitation using a critical daily mean temperature threshold of -1˚C in their calculations of water balance. When compared to observed snowfall data for the Muskoka (Figures 2.3 and 2.4) climate station, an empirically-derived threshold of both minimum (≤ 0˚C) and maximum daily temperature (≤ 4˚C) improved the accuracy of distinguishing snowfall and rainfall events by 4 to 5%. Therefore these criteria were used in the snow cover simulation.

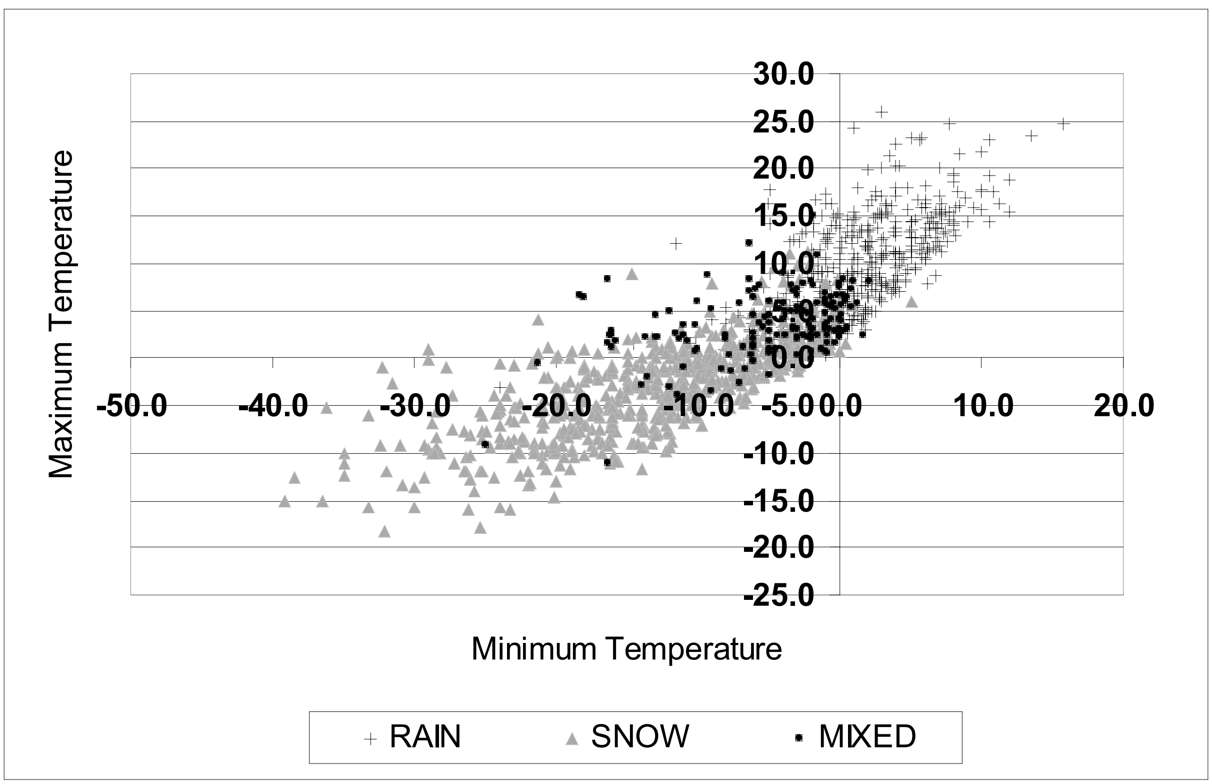


Figure 2.3: Snow, Rain, and Mixed by Tmin-Tmax: Muskoka (1980-90)

Freshly fallen snow can have a range of densities (also known as snow to liquid ratios) depending upon several interrelated factors: upper air and surface temperatures, crystal type and size, cloud physics and wind speed. For the purposes of estimating snow accumulation in the Canadian Daily Snow Depth Database, a constant snowpack density of 300kgm^{-3} (or 0.3) was assumed (after Brown and Braaten, 1999). This figure was also used in the current analysis to adjust the density of new fallen snow prior to its addition to the snowpack.

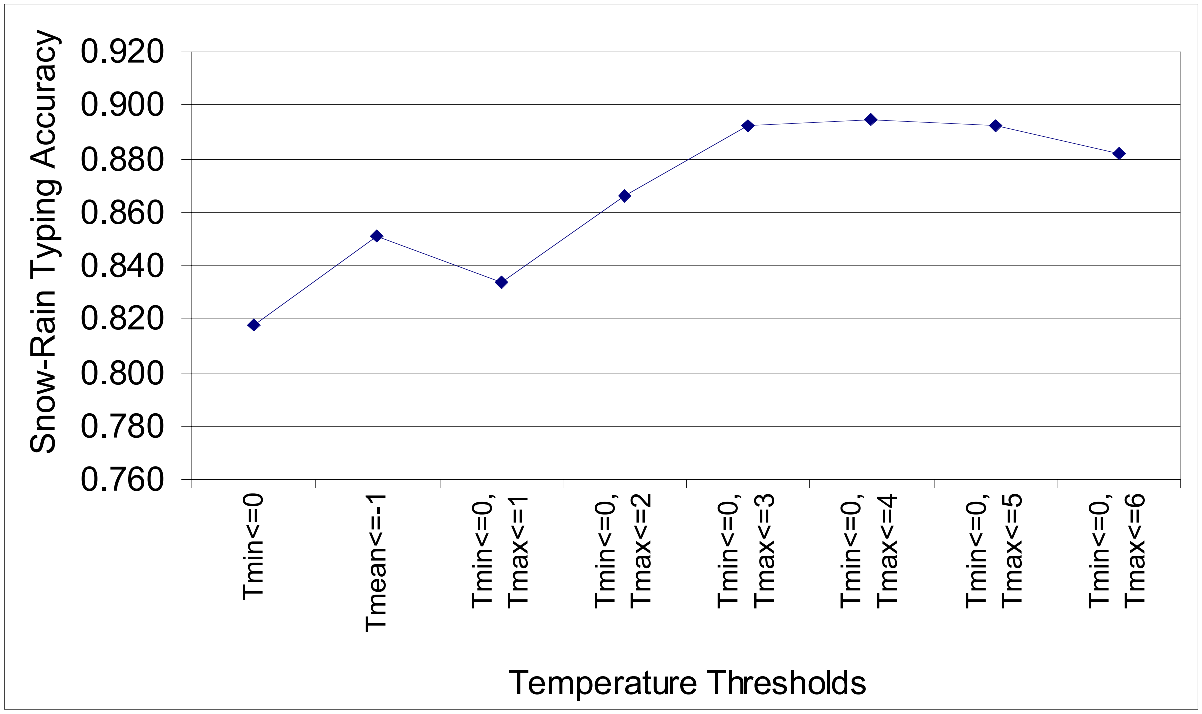


Figure 2.4: Precipitation Typing Accuracy: Muskoka (1980-90)

Finally, an empirically derived equation originally developed by the US Army Corps of Engineers (1956) was used to estimate daily snow melt:

$$M = k[(1.88 + 0.007R)\ (9 / 5T) + 1.27)],\ T > 0$$

where:
M is snowmelt water (mm day $^{-1}$)
k is a locally-calibrated snowmelt factor
T is mean daily air temperature (°C); and
R is mean daily rainfall (mm).

Note: T and R were provided for each time series (2010-39, 2040-69, 2070-99) by output from the LARS-WG

Since only daily rainfall and mean temperature data are required by the equation, it was found to be suitable for the current study. Brown and Braaten (1999) added the locally calibrated snowmelt factor to the original equation. It was excluded (*i.e.*, assumed to equal 1.0) for this analysis since it represents a separate, station-specific empirical correction factor that does not apply equally throughout the entire study area. The validity of the approach was tested using observed data from the 1980-90 period for the Muskoka and Wiarton primary climate stations. A reasonable fit occurred for most years. Figure 2.5 illustrates the observed and simulated snow depth at Muskoka station.

Length of snow season indicators is of particular interest to this study. Estimated and observed season lengths for two, 10 and 30 centimetres (cm) snow depth thresholds were compared for Muskoka. As the depth threshold increases, the difference between estimated and observed sea-

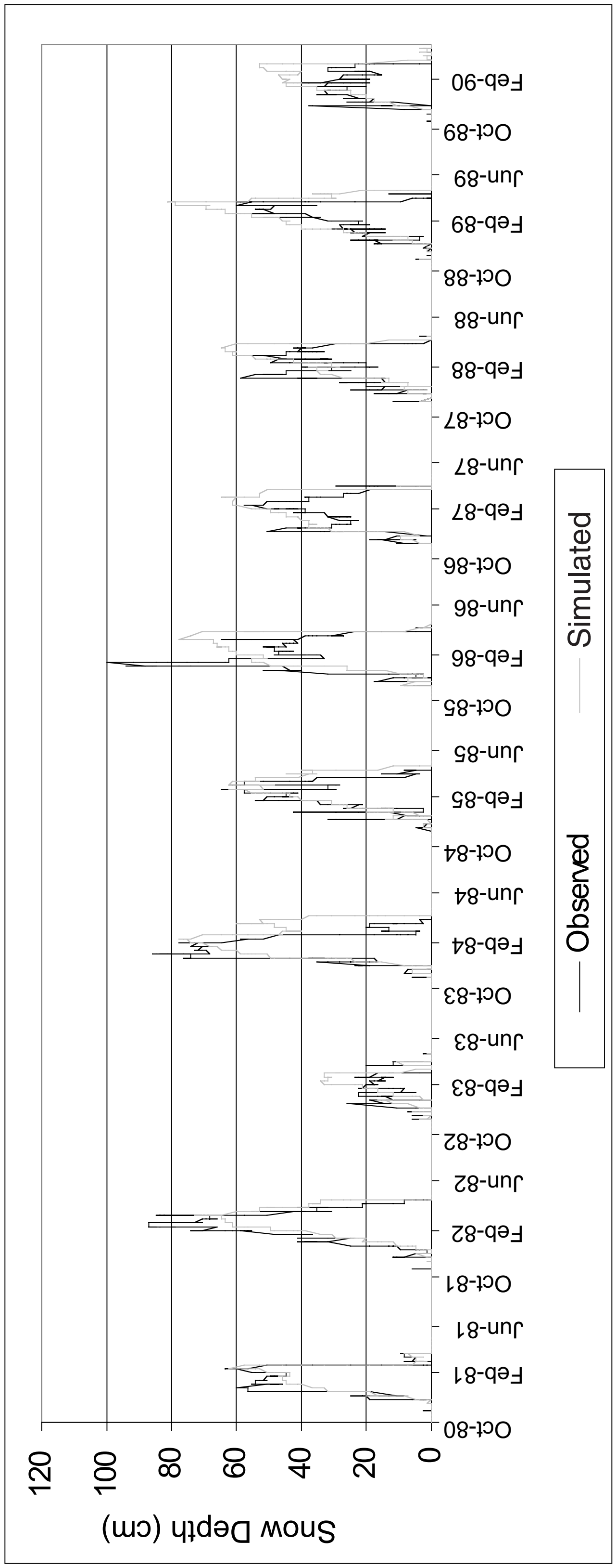


Figure 2.5: Observed and Simulated Snow Depth at Muskoka Station, 1980 to 1990

son length increases, thus confidence in the predicted values decreases. Average differences over the entire 29-season period are relatively small for the two (3%), five (6%), 10 (7%) and 30 cm (14%) thresholds. These results suggest that the method is suitable for comparing potential shifts in the statistics of 20 or 30-year periods as required for this study. Comparison of individual years is much less reliable.

Snowmaking Module

To complete the climate data set, a snowmaking module was integrated with the snow cover model at the locations of the five alpine ski areas. The estimated technical capacities and decision rules for the snowmaking module were derived from communications with ski industry stakeholders in the study area and are summarized in Table 2.2. The goal of the snowmaking module was to produce skiable terrain between November 26th and March 30th for each year. These dates were established upon review of average opening and closing dates of ski areas in the study area and define the 'snowmaking window' for this study. If natural snowfall had not produced skiable conditions by November 23rd, the snowmaking module would begin to produce snow on days when snowmaking was technically possible (defined as days with minimum temperature of -5ºC or less with average humidity levels in the study area taken into account). The ability of snowmaking equipment to produce different densities of snow was not incorporated into the snowmaking module. The snowmaking module was designed to maintain a 50 cm snow base, a level established from analysis of reported snow depth at ski areas during the 1990s. If the snow depth during the snowmaking window was below the 50 cm threshold and temperatures were suitable for snowmaking, the snowmaking module would produce snow to a maximum of 10 cm per day. The value of the maximum amount of snow made in a day was derived from the capacities of three of the more advanced snowmaking systems at ski areas in the study. In two cases ski area operators claim to have the capacity to go from virtually zero snow cover conditions to skiable terrain over the majority of their resort in a three to five day period. In short, zero snow to a desired opening snow depth of approximately 30 cm in three days (or 10 cm per day).

Anticipating technological improvements in snowmaking systems, the study also parameterized a snowmaking module with improved capacities (Table 2.3). Two technological advancements were anticipated: the ability to make snow at a warmer temperature and the capacity to make more snow per day. Snowmaking is already possible at temperatures warmer than the -5˚C used to parameterize the snowmaking module for 'current snowmaking technology' analyses. However, it is less efficient and thus more costly, and sometimes requires the addition of additives such as Snowmax, which raises the cost further. The temperature threshold for efficient snowmaking in the 'improved snowmaking technology' scenario was -2˚C. Improving the capacity to make more snow per day requires further investment in snowmaking infrastructure (larger water sources, higher pumping capacity, additional snow guns and improved control systems).

Table 2.2: Climate Thresholds for Snowmaking

	Suitable Conditions			Economic/Excellent Conditions		
Literature	**Temperature**	**Humidity**	**Wind**	**Temperature**	**Humidity**	**Wind**
Lynch *et al.* (1981)	daily max -2.2°C					
Lamothe and Periard (1988)	daily max < 0°C					
Konig (1998b) Australia	< -5°C	< 65%	-	-	-	-
Ordower (1995)	-2°C mean					
Equipment Suppliers[a]	**Temperature**	**Humidity**	**Wind**	**Temperature**	**Humidity**	**Wind**
Areco Snowmaking Co. (2000)				min -3°C		
Killington Snowmaking Co. (2000)	-1°C absolute limit	0%				
Paoli Peaks (2000)						
Excellent	-9°C	50%				
Good	-4°C	50%				
Marginal	-3°C	40%				
HKD Spectrum System (2000)	-2.2°C upper limit					
Ski Areas	**Temperature**	**Humidity**	**Wind**	**Temperature**	**Humidity**	**Wind**
Sir Sam's (Bishop, 2000)	-5°C	typical for season	-			
Etobicoke Centennial Park (Dureau 2000)	-5°C					
Blue Mountain (2001)	start at -5°C					

a - Source: Company/Organization Websites.

Table 2.3: Snowmaking Module Technical Capacities and Decision Rules

	Current Snowmaking Technology	Improved Snowmaking Technology
Technical Capacity		
• minimum temperature for efficient snowmaking	-5ºC	-2ºC
• snowmaking capacity/day over entire skiable terrain of ski area	10 cm	15 cm
Snowmaking Decision Rules		
• snowmaking window	Nov. 23 – Mar. 30	Nov. 23 – Mar. 30
• snow base depth to maintain	50 cm	50 cm

Recreation Climatology Analysis

Weather and climate are interconnected with recreation and tourism in many different ways. Yapp and McDonald (1978), Mieczkowski (1985) and Harlfinger (1991) have all explored the use of 'recreation-climate' indices to evaluate the recreation climate potential of a selected area. Paul (1972) proposed general relationship curves between a range of recreational activities and weather variables. Correlating actual recreation data (*e.g.*, lift tickets, snowmobile counts, trail passes, ice hut rentals, etc.) with climate data to develop empirical relationships and validate thresholds is a research need that has persisted for 20 years (Wall, 1992; Smith, 1993). Other recreation climatology research has endeavoured to define climatic thresholds for individual recreational activities. For example, Crowe *et al.* (1977) defined a suitable alpine ski day as one with at least six hours with 2.5 cm of snow depth, an air temperature between -2ºC and +5ºC, wind speeds of less than 6.5 ms^{-1}, no liquid precipitation and visibility of more than 800 metres. The alpine ski season was defined as the number of days between the first and last days with recorded snow depth of 2.5 cm (Crowe *et al.*, 1977). These types of climatic thresholds have been used previously in climate change sensitivity analyses of winter and summer recreation including alpine skiing (McBoyle and Wall, 1987; Wall, 1988; Lipski and McBoyle, 1991; McBoyle and Wall, 1991), camping (Wall, 1988), golfing (Hatt and McBoyle, 1992), and recreation in general (Hind, 1988).

Climatic Thresholds for Winter Recreation

The climatic thresholds available in the literature for alpine skiing, snowmobiling and nordic skiing were compiled for this analysis and are presented in Table 2.4. Many of the thresholds in the literature were based on consultations with recreation experts and industry stakeholders. Industry stakeholders in the study area were also consulted regarding proposed climatic thresholds to define more clearly climate thresholds from an industry perspective, assess whether there were any regional differences relative to the literature and examine whether thresholds had evolved over time (*e.g.*, lower temperatures for snowmaking as a result of improved technology, deeper snow depth requirements due to changes in snowmobile design). The climatic thresholds recommended by tourism and recreation industry stakeholders from the Lakelands study area are also presented in Table 2.4.

The ability of the climatic threshold approaches available in the literature to simulate recreation seasons has not been assessed. The lack of appropriate recreational data has remained a primary barrier. Where a range of climatic thresholds has been proposed in the literature, there has been no comparison of their relative performance versus actual conditions. As such, the influence of adopting different thresholds to simulate recreation seasons on the results of climate change impact assessments remains unexplored. In order to produce more robust simulations of recreation seasons under climate change conditions, this study compared the ability of different climatic thresholds to simulate observed recreation seasons. Detailed recreation data (primarily whether the recreation activity was occurring or not) and pertinent conditions (*e.g.*, snow depth) were required to compare the accuracy of different climatic thresholds.

Table 2.4: Climatic Thresholds for Recreation Activities

Alpine Skiing	Natural Snow Cover	Temperature	Precipitation	Visibility	Wind
Gates (1975)[1]	> 1 inch > 2.5 cm	> 6°F > -14°C	little or none	> 1/2 mile > 800 metres	< 15 mph < 24 km/h
Crowe *et al.* (1977)[1]	> 1 inch > 2.5 cm	> 6°F > -14°C	none or light snow	> 1/2 mile > 800 metres	< 15 mph < 24 km/h
Lamothe and Periard (1988)[2]	min 30 cm (no snow making)	favourable > -13°C unsuitable < - 25°C (with windchill)	no liquid precipitation	sunshine is desirable but does not effect skiable day	-
Breiling *et al.* (1997)	30 cm	-	-	-	-
Witmer (1984)	30 cm	-	-	-	-
Konig (1998b)	30 cm				
Etobicoke Centennial Park (Dureau, 2000)	13 cm (regardless of how it gets there)				
Sir Sam's (Bishop, 2000)	30 cm base (because it is rocky) 15 cm base (if smoothed out like Horseshoe)				
Snowmobiling	**Natural Snow Cover**	**Temperature**	**Precipitation**	**Visibility**	**Wind**
Gates (1975)[1]	> 1 inch > 2.5 cm	> 6°F > -14°C	little or none	> 1/2 mile > 800 metres	< 15 mph < 24 km/h
Crowe *et al.* (1977)[2]	> 2 inch > 5 cm[2]	max < 40°F < 4.5°C	no liquid precip for 24 hrs	> 1/2 mile > 800 metres	-
Schliefenbaum (2000)	15 cm = sufficient, 30 cm = preferred	even below 0°C, strong sunshine can deteriorate trails			
Nordic Skiing	**Natural Snow Cover**	**Temperature**	**Precipitation**	**Visibility**	**Wind**
Crowe *et al.* (1977)[1]	> 1 inch > 2.5 cm[1]	min > -21°C	no liquid precip for 24 hrs	> 1/2 mile > 800 metres	< 15 mph < 24 km/h

[1] - at least five hours (between 10 am and 6 pm)
[2] - at 7 am

The OMTCR issues a daily summary of snow conditions at ski centres in Ontario and some ski areas near the Ontario-Québec border. The information is compiled at the Barrie Tourism Office, which indicated that, in spite of a few gaps, it possessed archived data for the period 1981-99. A formal data-sharing request was granted for the purpose of this study. The data set obtained contained the daily ski conditions, including whether the ski area was in operation, snow depth, snow conditions, ski runs open and snowmaking activities, for all Ontario alpine and nordic ski areas. While the ski conditions data were self-reported and thus open to subjective assessment, inaccurate reporting (as determined through random inspections by OMTCR staff) results in the ski area being suspended from the Ministry's ski report. The risk of lost revenue is a strong deterrent to inaccurate observations, thus the archived database is believed to be a reliable representation of ski conditions.

Similarly, the OFSC co-ordinates trail condition reporting in Ontario. Over 200 member snowmobile clubs report local trail conditions to a district co-ordinator. Each of the 16 districts that cover the province then reports to the OFSC head office, which then issues the weekly trail condition report. Although snowmobile trail condition reports were periodically issued through newspapers in the 1970s and early 1980s, for the last 10 to 15 years they have been issued through electronic media (TV, radio and more recently the Internet). The OFSC stopped keeping files of the reports in the early 1990s and all other attempts to locate archived trail condition data for the province were unsuccessful. The only measure of the snowmobile season length in the study area that could be obtained was average season length estimates used by the OFSC to calculate trail grooming costs and payments to local snowmobile clubs. While average season length did not reveal the impact of climatic variability on season length, it was a useful measure for validating the simulated seasons produced with different climatic thresholds.

Having obtained measures of winter recreation season lengths for the study area, the ability of a range of climate thresholds available in the literature and some defined through communication with winter recreation industry stakeholders (Table 2.5) to simulate winter recreation season length was tested at selected sites in the study area. The performance of the various thresholds is compared for each winter recreation activity.

Table 2.5: Climate Thresholds Used in Recreation Season Simulation Calibration Analysis

Simulation Model	Tmax (°C)	Tmean (°C)	Tmin (°C)	Rain (liquid) (mm)	Natural Snow Depth (cm)	Snowmaking Integrated
Alpine Skiing						
Crowe '77	< 4	-	-	0	> 5	no
Lamothe '88	< 10	-	-	0	> 30	no
Lamothe '88+SM	< 0	-	-	0	> 10	partially
Ski Sim	< 10	-	-	<20 mm in 2 days	>=30	yes
Snowmobiling						
Crowe '77	< 4	-	-	0	> 5	N/A
SimSM-10	< 2	-	< 0	0	> 10	N/A
Nordic Skiing						
Crowe '77	< 4	-	-	0	> 5	no
SimXC	< 5	-	< 0	< 5	> 7.5	no

Alpine Skiing

A range of climatic thresholds for alpine skiing available in the literature was examined for its ability to simulate the observed ski season at the five ski areas chosen for this study (listed in Table 2.1). Examination of daily performance indicated that the climatic thresholds (*i.e.*, liquid precipitation, maximum temperatures - see Table 2.4) that defined unsuitable ski conditions (*i.e.*, non ski days) were frequently exceeded. The season length simulated by some of the climatic thresholds available in the literature was substantially shorter than observed season lengths. Figure 2.6 illustrates the observed season length for the Horseshoe ski resort and the simulated season produced with climatic thresholds from Crowe *et al.* (1977) and Lamothe and Periard (1988) (with and without a snowmaking adjustment) (Table 2.5).

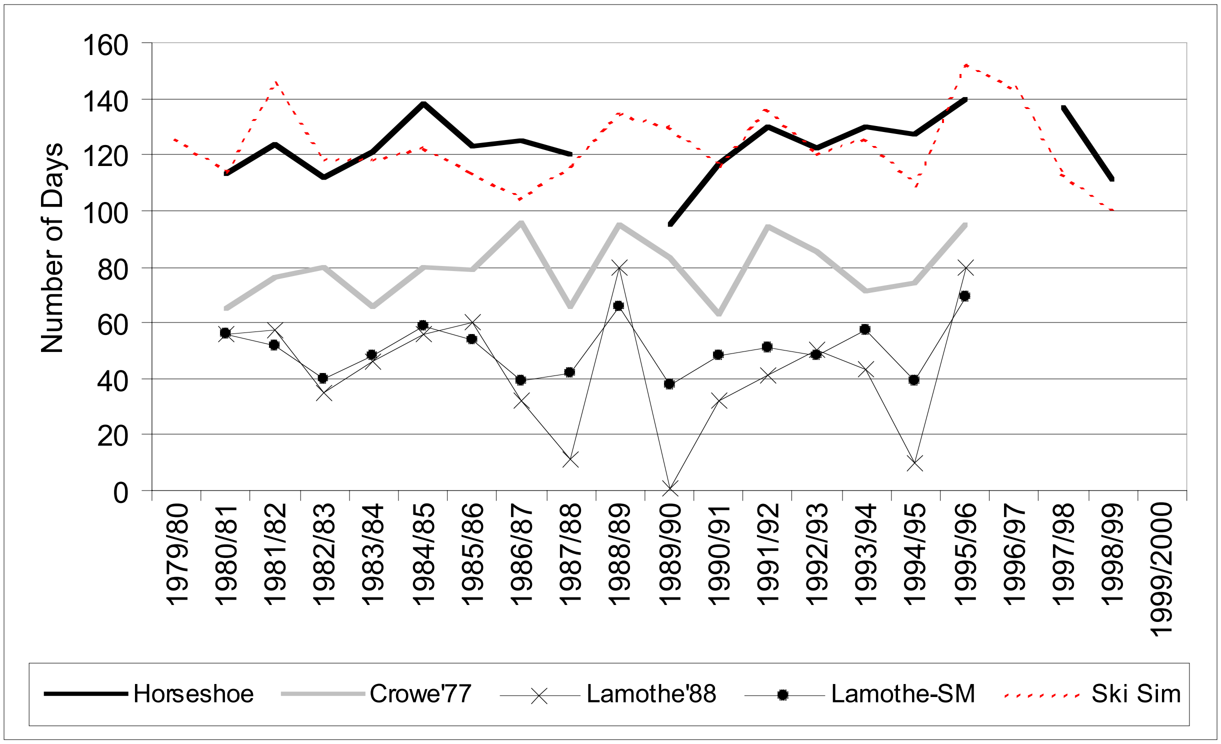


Figure 2.6: Horseshoe Alpine Ski Season - Observed and Simulated, 1979/80 to 1999/2000

Two points are noteworthy from this comparison. First, while the thresholds defined by Crowe *et al.* (1977) (labelled 'Crowe'77') generally performed better, both approaches consistently under-estimated the season length for Horseshoe. In some years, the natural snow condition thresholds set out by Lamothe and Periard (1988) (labelled 'Lamothe'88') predicted a very limited ski season (less than 20 days - *e.g.*, Horseshoe 1987/88, 1994/95) or eliminated the season altogether (*e.g.*, Horseshoe - 1989/90). In each of the three examples listed, the actual ski season at Horseshoe was at least 100 days longer than the Lamothe and Periard (1988) approach predicted. Second, the season length predicted by the two approaches for individual years differed by approximately 10 to 85 days over the 15 ski seasons simulated. The difference in the simulated seasons produced by the two approaches in certain years was such that it would likely mask any change in the season length resulting from climate change. This comparison illustrates the importance of calibrating simulated recreation seasons with the observed record before attempting to model potential changes in season length resulting from projected climate change.

The climate thresholds used to parameterize the ski season simulation model (labelled 'Sim') in this analysis were refined through examination of the observed ski operations data and communications with ski industry stakeholders. The snow depth thresholds used by Crowe *et al.* (1977) were deemed unrealistic and dismissed in favour of a minimum 30 cm snow-base level recommended by stakeholders. Analysis of the thresholds for minimum and maximum temperature and precipitation available in the literature, found they were exceeded frequently in the observed operational data. Ski operations rarely closed because of cold temperatures and the minimum temperature was consequently dropped from the variables used in 'Sim.' Winter melts needed to be multi-day in order to cause a closure of ski areas. To adjust for this, ski areas were modelled to close if maximum temperatures exceeded 10ºC for two consecutive days and were accompanied by liquid precipitation or when the two-day liquid precipitation > 20 millimetres. Figure 2.6 reveals that the 'Sim' performed much better than the simulations based on climate thresholds in the literature.

A comparison of the observed and simulated (Sim) ski seasons at Horseshoe ski area revealed that over the 17 years that observed data were available, the average season length was 124 days and 123 days, respectively (minimum seasons were 111 and 100 days and maximum seasons 140 and 152 days). When the simulation error caused by the Horseshoe ski area operating with a snow base less than the specified desired level of 30 cm (usually occurring at the beginning of the ski season) was adjusted for, the ski season simulation performed reasonably well, missing the observed season length by more than seven days (approximately 5% of an average season) in only five of 17 years.

Nordic Skiing and Snowmobiling

The procedure for establishing climate thresholds for the two trail-based recreation industries (Nordic skiing and snowmobiling) was very similar to that of alpine skiing. In both cases, the only thresholds available in the literature were those proposed by Crowe *et al.* (1977) (Table 2.5). Thresholds were compared to observed season lengths at the six Nordic ski areas for which observed data were available. The simulation performed reasonably well and the minor adjustments incorporated into ('SimXC') (Table 2.5) further improved the simulation performance (Figure 2.7).

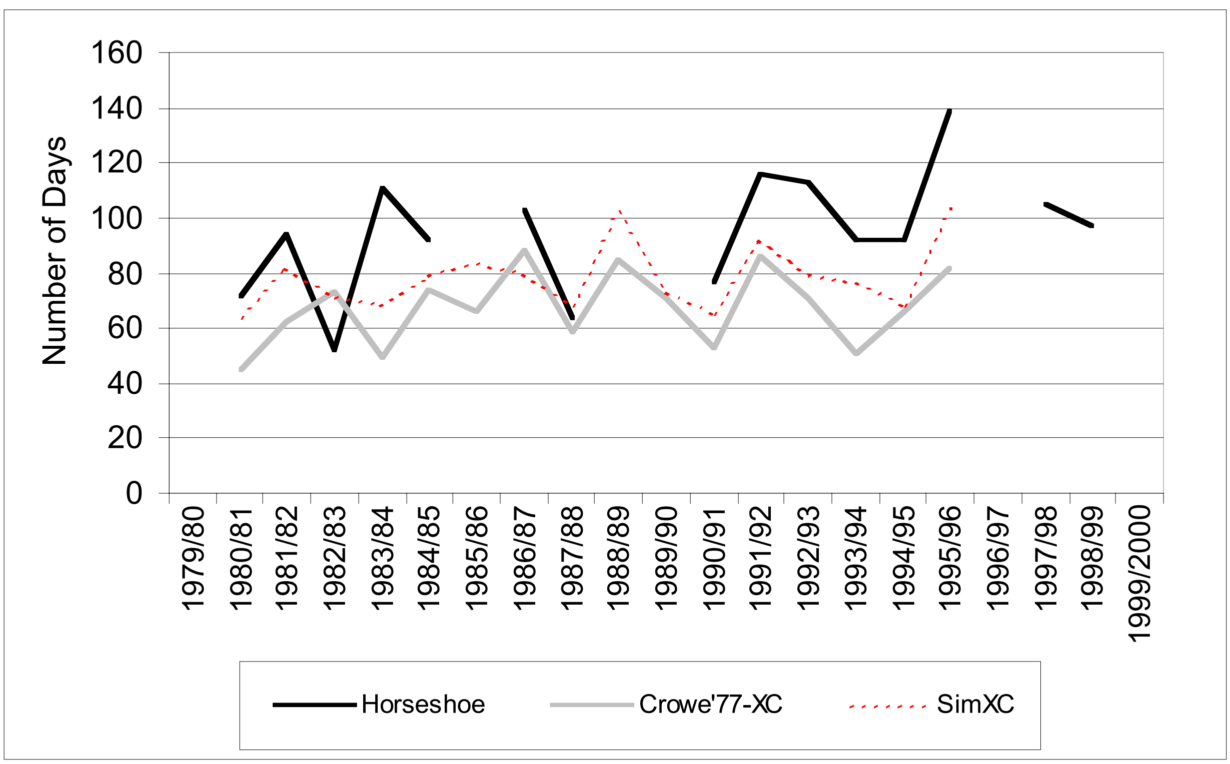


Figure 2.7: Horseshoe Nordic Ski Season - Observed and Simulated, 1979/80 to 1999/2000

Snowmobiling

With no equivalent observed daily data set of trail conditions for snowmobiling, the process for establishing and testing climate thresholds for the season simulations differed slightly. The simulated season produced by Crowe *et al.*'s (1977) thresholds (Table 2.5) were compared to the average season length range provided by the OFSC. At each of the seven snowmobile areas examined (Table 2.1), the simulation typically fell within the upper margins of the range provided by the OFSC or slightly above (Figure 2.8). Modifications to the snow depth threshold ('Sim-SM10'), so as to incorporate a minimum snow depth more consistent with that indicated by industry stakeholders (see Tables 2.2 and 2.4) resulted in a reduced average season length that was near the lower bound of the OFSC range (Figure 2.8).

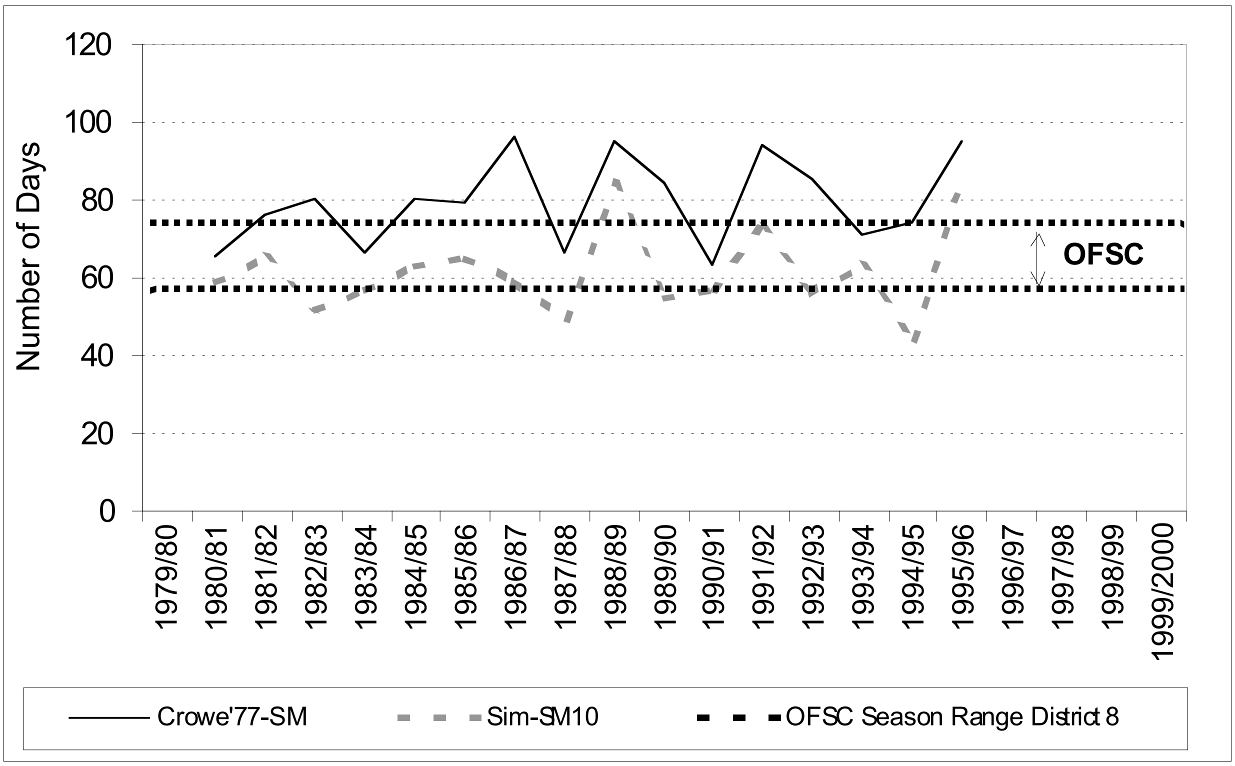


Figure 2.8: Orillia District Snowmobile Season - Simulated, 1979/80 to 1999/2000

Research Design for Ice Fishing

The value of lake ice in the context of tourism and recreation is a theme that has had little exploration. Ice conditions are the primary determinant for ice fishing, necessitating a different methodological approach than that used for the three snow-based winter recreation activities described in the previous section. The main data requirements for the research design were generally the same as the snow-based activities. Historical ice condition data were sought in order to conduct the sensitivity analysis to current climate variability. These data were obtained from Environment Canada ice monitoring stations in the study area and the OMTCR office in Barrie (located on the shores of Lake Simcoe). Ice condition scenarios under projected climate change were derived from a recent study by Fang and Stefan (1998). Recreation data, including ice safety thresholds and historic season lengths, were compiled through stakeholder interviews

(Appendix B) and the Lake Simcoe Fisheries Assessment Unit (OMNR). Details on each of the components of the ice fishing research design are provided below.

Historical Lake Conditions Data

An inventory of Environment Canada lake ice monitoring stations within the study area determined that ice conditions data were only available at five locations. The location of the ice stations and the years in which ice thickness data were recorded are summarized in Table 2.6. Unfortunately, most of the stations were not located in key ice fishing areas.

Table 2.6: Lake Ice Monitoring Stations in the Lakelands Region

Station	Station Name	Body of Water	Period of Record	Latitude	Longitude
YQA	Midland	Georgian Bay	1979-96	44.75	78.11
T23	Jackson's Point	Trent-Severn	1977-89	44.33	78.59
T24	Atherley	Trent-Severn	1977-89	44.57	78.60
T25	Lake Couchiching	Trent-Severn	1977-89	44.71	78.61
T26	Sparrow Lake	Trent-Severn	1977-89	44.79	78.56

Midland was the only station that recorded ice thickness on a weekly basis and thus provided a data set useful for the historical climate sensitivity analysis. The other four stations only recorded ice thickness measurements once a year, usually from February 20th to 22th. While the data from these stations illustrate how ice conditions vary from location to location within the study area and also inter-annually (Table 2.7), the temporal resolution was of limited use for this study.

Table 2.7: Lake Ice Thickness (cm) Variability in the Lakelands Region (1980 - 89)

Year	Midland (maximum seasonal ice thickness)	Feb. 20-22 Period: Midland	Jackson's Point	Atherley	Lake Couchiching	Sparrow Lake
1980	48 cm (Mar. 16)	38	40	25	37	37
1981	58 cm (Feb. 22)	58	55			
1982	58 cm (Feb. 28)	45	62	45	58	55
1983	43 cm (Feb. 27)	41	41			
1984	43 cm (Feb. 19)	43	36		50	44
1985	35 cm (Feb. 10)	31	44	38	42	46
1986			51		46	47
1987			41	27	56	44
1988			42		38	
1989			43	9	48	51
Mean	47.0	42.6	45.5	28.8	46.9	46.3

Landsat imagery of the patterns of freeze-up and break-up on Lake Simcoe provided additional insight into the characteristics of ice cover on Lake Simcoe. In general, it can be said that the lake freezes from east to west in accordance with the increasing depth of the lake as one travels in the same direction. Shallower areas (*e.g.*, Cook's Bay) freeze first, as do areas that are sheltered from the wind such as areas behind islands or in bays. Kempenfelt Bay is one of the deepest areas of Lake Simcoe; while it is sheltered from the wind to some degree, its greater water depth delays the onset of freezing. Thaw thus occurs in the opposite fashion to freeze-up, with ice break-up occurring in shallower areas first.

Climate Change Scenarios for Lake Ice

Fang and Stefan (1998) modelled ice thickness, ice cover, freeze-up and break-up dates under doubled CO_2 conditions for small lakes (< 13 metres deep) in the northeastern United States. Using both climatological variables and lake parameters, Fang and Stefan (1998) simulated the effects of projected climate change on the ice cover of 27 types of lakes at 209 locations across the contiguous US. Though not specifically designed to examine ice conditions on Canadian lakes, the study included ice data from some US locations that possessed the same latitude as the Lakelands study area (northern Michigan, northern New York and Vermont). A check of the modelled baseline found that Fang and Stefan's (1998) results for maximum ice thickness were consistent with recorded data at several locations in the study area. Consequently, Fang and Stefan's (1998) climate change scenarios for ice cover were also considered a reasonable estimation of the impact in the study area.

Recreation-Climatology Analysis

A sample of ice hut operators was interviewed and data collected on lake ice safety thresholds, historical season lengths and business models. Operators were selected in order to demonstrate the variability in season length and operator safety thresholds in key ice fishing areas, particularly Lake Simcoe. The ice safety thresholds identified by stakeholders are summarized in Table 2.8. In general, 15 to 20 cm is considered a safe range for placing ice huts on Lake Simcoe. The type of vehicle used to transport people is also dependent on ice thickness. For example, the operator at Jackson's Point will transport clients at a 15 cm thickness with an ATV and sleigh, but requires a threshold of 30 cm before a heavier vehicle such as a bombardier will be used. Ice huts must be removed from most bodies of water in the study area by March 15th. The Ontario Ministry of Natural Resources (OMNR) enacted the 'hut-off' rule because many people were unable to determine when to remove their huts. This uncertainty often resulted in unsafe conditions for retrieval operations and the subsequent loss of many huts. The ice fishing season can continue past the March 15th hut-off deadline as long as the fishing regulations are followed and the ice can safely support the weight of ice fishers.

Table 2.9 summarizes the ice fishing season length for the last four years at six locations in the study area. Two methods were used to collect these data. First, several hut operators participated in personal interviews during the winter of 2000/01. In some cases, the quality of season length data was uncertain because written records of hut-on and hut-off dates had not been systematically archived. Fortunately, the accuracy of their data could be validated using records provided by the OMTCR in Barrie, Ontario. These weekly records of ice thickness and open-closed dates for ice hut operators have been collected by the OMTCR since the 1998 season. Ice hut operators are contacted by OMTCR every Thursday during the ice fishing season. Where discrepancies between hut operator and OMTCR reports existed, OMTCR data were taken to be correct.

Table 2.8: Ice Hut Operator-Defined Ice Safety Thresholds

Station	Stakeholder Location	Body of Water	Operator Threshold (for hut on date)	Operator Threshold (for hut off date)
YQA	Midland	Georgian Bay	25 cm (blue/black ice)	
T23	Jackson's Point	Lake Simcoe	15 cm (clear black ice) and entire lake frozen	OMNR imposed date
A	Kempenfelt Bay	Lake Simcoe	15-20 cm (clear blue ice) and entire lake frozen	*ice block stress test
B	Cook's Bay	Lake Simcoe	20 cm (clear ice)	OMNR imposed date
C	Carthew Bay	Lake Simcoe		OMNR imposed date
T24	Atherley	Lake Simcoe		OMNR imposed date
T25	Lake Couchiching	Trent-Severn	15-20 cm (clear black ice)	OMNR imposed date
T26	Sparrow Lake	Trent-Severn	20 cm (clear black ice)	OMNR imposed date

* This technique consists of cutting a large block from the ice with a chainsaw and smashing it on a concrete floor to document how the block breaks. A block that breaks into many pieces, for example, indicates weak ice.

Table 2.9: Ice Fishing Season Lengths (1997/98 - 2000/01)

	1997/98			1998/99			1999/2000			2000/01		
Ice Hut Operator	**Hut On**	**Hut Off**	**Season Length (days)**	**Hut On**	**Hut Off**	**Season Length (days)**	**Hut On**	**Hut Off**	**Season Length (days)**	**Hut On**	**Hut Off**	**Season Length (days)**
Midland	Jan. 17	Mar. 05	45	Jan. 16	Mar. 15	59	Jan. 13	Mar. 02	50	Dec. 24	Mar. 15	82
Jackson's Point	Jan. 26	Mar. 01	35	Jan. 26	Mar. 06	40	Jan. 19	Mar. 04	46	Jan. 03	Mar. 15	72
Kempenfelt Bay	Feb. 05	Mar. 01	25	Jan. 29	Mar. 12	43	Jan. 22	Feb. 27	37	Jan. 06	Mar. 15	69
Cook's Bay				Jan. 19	Mar. 15	56	Jan. 12	Mar. 12	61	Dec. 21	Mar. 15	85
Lake Couchiching	Jan. 20	Mar. 03	43	Jan. 18	Mar. 14	69	Jan. 15	Mar. 02	48	Dec. 29	Mar. 15	77
Sparrow Lake				Jan. 08	Mar. 16	68	Jan. 10	Mar. 15	66			

Source: Stakeholder Interviews; OMTCR, Barrie Office.

Despite having only four years of ice fishing season data from the OMTCR, the data facilitated analysis of current sensitivity by calculating the difference in season length between a normal winter (2000/01) and the record warm winter of 1997/98. With the winter of 1997/98 approximating an average projected winter under some doubled-CO_2 scenarios, the 1997/98 ice fishing season served as an analogue for an average ice fishing season in the 2050s.

Economic Analysis

Tourism data from Chapter 1 indicated 'what's at risk' in terms of recreation-related expenditures in the Lakelands Region for each of the four winter activities. Unfortunately, not all the data are of the same detail and precision. The absence of suitable economic data for the tourism and recreation sector in the study area is a major impediment to assessing the economic impact of projected climate change. The economic impact analysis for this study consisted of two components. First, the current economic baseline was estimated for the four individual winter recreation industries examined in this study. The second stage of the economic analysis involved the construction of an economic scenario for winter recreation in the early 2020s. Reference to the 2020s is used in order that there be a common time-frame between the value of the sector ('what's at risk') and the climate impact assessment.

Construction of Economic Baseline for Winter Recreation

Two methods were used to derive and estimate the value of the alpine skiing industry in the Lakelands Region. In 1999/2000, the Ontario Snow Resorts Association (OSRA) estimated the revenues of its membership at $300 million (Minardi, 2001). The OSRA was unwilling to provide a spatial breakdown of the market size of the ski industry in Ontario. However, based on the location of OSRA members (one-half of the ski areas that comprise the OSRA are located within the study area) and the assumption that each ski area in the province of Ontario is equal in terms of skier visits, the estimated value of alpine skiing in the study area would then be approximately $150 million in 1999/2000. Ski areas in the province vary in size and proximity to skier demand, and thus the proportions of skier visits are not equal. A 50% provincial market share for the ski resorts in the study area is a conservative estimate considering the ski areas in the Lakelands Region are some of the largest in Ontario and many are in an advantaged location of being approximately one-hour from Toronto, which has an estimated 11% of the active skiers in Canada (CSC, 2000).

The Georgian Bay area alpine skiing industry (which does not include all of the ski areas in the current study area) was estimated to be worth $51.9 million in the early 1980s (Lynch *et al.*, 1981). The average revenue growth of Canadian ski areas from 1985 to 1995 was 68% (Statistics Canada, 1996d). If this level of revenue growth is applied and extrapolated for the 1980-84 and 1996-2000 periods, then the estimated value of the Georgian Bay ski industry would be approximately $193 million in 2000. An important research need is for an independent study of the economic impact of the ski industry in the province, similar to those conducted in neighbouring provinces (Quebec - Archambault *et al*., 2000) and states (Michigan - Stynes and Sun, 2000).

Data on the number of Nordic skier days in the Lakelands Region were not available, nor was any estimate of the economic impact of this recreation activity. The Canadian Travel Survey indicated that in 1998 48,000 visitors to the Lakelands Region participated in Nordic skiing (Statistics Canada, 1999a) (Table 1.5). While this number does not capture local demand (individuals that travel less than 40 kilometres) or multiple skier-days by the same traveller, it was used as a conservative measure of Nordic skiing demand in the region. Using the estimated average expenditure per Nordic skier in Ontario (Table 1.6), it was estimated that the annual expenditures related to Nordic skiing in the Lakelands Region were approximately $8.9 million in 1999.

To estimate the value of the snowmobiling industry in the Lakelands Region, the number of OFSC trail permits sold was used as a proxy for the level of snowmobiling activity and related expenditures. Approximately 30% of all OFSC trail permits in Ontario were sold in the snowmobiling districts that cover the Lakelands Region. Assuming snowmobiling expenditures follow a similar ratio, it is estimated that the snowmobiling industry has an annual economic value of approximately $279.6 million.

The Lake Simcoe ice fishery generated approximately $28 million in recreation related expenditures in 1995 (LSEMS, 1995). Lake Simcoe is the major ice fishing area in the Lakelands Region and this economic value is taken as the minimum annual expenditure by ice fishers in the study area. Total angler days in Canada are valued at $2.5 billion, $1.75 billion for resident fishers and $655 million for non-resident fishers. Ontario's proportion of angler days is 33.1% for resident fishers and 65.5% for non-resident fishers, with respective estimated values of $579.3 million and $429 million ($1.008 billion in total). With ice fishing estimated at 11.5% of total angler days in the province, the Ontario ice fishing industry could be worth an estimated $116 million. The Lakelands Region accounts for 27% of angler days in Ontario. If the above assumptions are valid, the value of the ice fishing industry in the region is estimated at $31.3 million. This is a reasonable estimate for the entire Lakelands Region, given the estimate for Lake Simcoe ice fishery.

The estimated range of expenditures on the four winter related recreation industries in the Lakelands Region is $466.5 to $512.8 million. It has to be reiterated that these values are coarse estimates. Nonetheless, these economic estimates provide some measure of the baseline at risk to projected climate change. Economic assessments of the winter recreation sector (especially alpine skiing and snowmobiling) similar to those conducted in Michigan (Stynes *et al.*, 1998; Stynes and Sun, 2000) and other US states are required.

Construction of Economic Scenarios for 2020

Socio-economic change will have a significant effect on the future of the winter tourism industry in the study area. The economic scenario developed for the 2020s considered past growth rates (where available) and the potential impacts population growth and demographic change will have on participation in the four recreational activities being examined in this study. There is also a range of other potentially important factors that are beyond the scope of this research. These factors and the potential direction (positive or negative) of their impact on winter tourism are listed in Table 2.10. In addition, there is a need to develop stronger socio-economic scenarios for climate impact assessments that encompass compatible time scales (Berkhout and Hertin, 2000; Lorenzoni *et al.*, 2000). Subsequently, the climate, social and economic conditions that are discussed below are in reference to the 2020s.

The population of Ontario is expected to grow 30.6% from 1996 to 2021 (Ontario Ministry of Finance, 2000). Of greater relevance to the Lakelands Region is the expected population growth in the region and in the GTA, which is the primary tourism market for the region. The largest population growth in the Lakelands Region from 1996 to 2021 is expected to occur in Simcoe County (+68%) and the District of Muskoka (+40%), thus increasing local recreational demand. Other counties further away from the GTA are expected to grow, but at a much slower rate (Haliburton

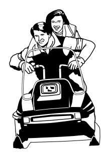
+18%, Grey +9% and Bruce +6%). The population of the GTA is expected to grow 45% to an estimated 6.95 million by 2021. As such, the population base for the primary tourism market of the Lakelands Region will be growing faster than the provincial average.

Table 2.10: Other Influences on the Winter Tourism Sector

Changes to the Business Context:	Potential Impact (+/-)
• Fuel price increases may adversely impact participation in motorized recreation (*e.g.*, snowmobiling) or alter leisure travel patterns.	-
• Low value of the Canadian vs the US dollar keeps more Canadians travelling at home and draws more American visitors.	+
• Demographic trends may continue to alter participation in certain recreational activities (*e.g.*, baby-boomers move away from more physically strenuous activities such as skiing).	+/-
• Improved or diminished transportation access may alter business advantages of certain recreation areas.	+/-
• Lakelands marketing strategy to promote winter tourism is successful and increases winter tourism market size.	+
• The introduction of year-round schooling and elimination of the two month summer school holiday could have an important impact on the seasonality of tourism in the Lakelands Region, perhaps shifting some summer recreation demand to winter.	+/-
• The recreation community lifestyle trends continues to grow, increasing the local market for winter recreation.	+
• The magnitude of climate change impacts may be greater in other recreation areas (*e.g.*, Michigan skiing, ice fishing in the Bay of Quinte), perhaps resulting in the loss of competitors and a net transfer of tourism business to the Lakelands Region.	+
• Decreased snowfall in source areas of skier (*e.g.*, Toronto) worsens the psychological effect of 'no snow in town, no snow on the ski hills', having an adverse impact on demand.	-
• Successive short winter recreation seasons cause some individuals to sell their equipment (*e.g.*, skies, snowmobile), reducing participation and winter recreation demand.	-
Adaptations to Climate Change:	
• Further investment of adaptation technologies (*e.g.*, snowmaking) could reduce the impacts of climate change.	+
• Behavioural adaptations by winter recreation participants (*e.g.*, compressing the same amount of skiing activity into a shorter season, switching from preferred fish species to another) may result in little net change in related expenditures in the short term.	+
• Recreation substitution (*e.g.*, using ATVs instead of a snowmobile) could also reduce climate change related losses in winter recreation expenditures.	+

Studies have examined recreation participation patterns and demographic change (Robinson, 1987; Murdoch *et al.*, 1990). Building on this research, Foot (1992) used population projections in combination with recreation participation data from the Ontario Leisure Activity Participation Survey to project changes in recreation participation from 1990 to 2015. Of relevance to this study were the participation growth projections for alpine (+17.9%) and Nordic (+24.3%) skiing, snowmobiling (+17.6%) and fishing (+24.9%), all of which were below the estimated growth rate for the provincial population. Using recreation participation growth as proxy for expenditure growth and extrapolating the growth rate of the final five-year period (2011-15) to 2016-20, crude estimates of the value of the four winter recreation sectors were derived for 2020. The estimated range for the individual recreation sectors in 2020 were: alpine skiing $172.5-221.9 million, Nordic skiing $10.9 million, snowmobiling $321.5 million and ice fishing $34.2-38.2 million.

The results of the recreation season length analysis (% gain or loss) were then used to determine the potential economic impact, with the assumption that the proportional change in the recreation season and related expenditures would be similar. The economic impact assessment will assume all else will remain equal in the winter recreation sector and that only climate change will influence the physical resource.



CHAPTER THREE

Analysis

This chapter is divided into two parts. One part examines the current vulnerability of the four recreation sectors (alpine skiing, snowmobiling, Nordic skiing, and ice fishing) to current climate variability. The second part presents the climate change impact assessment results. In the interest of brevity, detailed results are presented for only one site within the study area (Horseshoe ski area and snowmobile district 8 - Orillia West). The results for the other four alpine ski areas, six snowmobile districts, and five nordic skiing areas are presented in summary form only. Ice fishing is discussed separately from the three snow-based recreation activities. The economic implications of climate change for each of the four winter recreation activities are then discussed.

Vulnerability to Current Climate Variability

The headlines compiled in Table 3.1 indicate that winter recreation in the Lakelands Tourism Region is vulnerable to current climate variability. The newspaper stories from which these headlines were taken describe the positive and negative impacts of winter snow and ice conditions for recreationists and the industries that support them. The winters of 2000/01 and 2001/02 are illustrative. As this report was completed, the lack of snow and temperatures cold enough for snowmaking in November and December of 2001 led to ski events being cancelled and concerns that ski areas might not be able to produce a sufficient snow base to open for the Christmas holiday, which accounts for 25-30% of their revenues. This stands in sharp contrast to the previous year, when large snowfalls in November led to one of the longest and most profitable ski seasons in the region. Some ski areas were open for as long as four months and were able to reduce their snowmaking costs substantially.

Alpine Skiing

An earlier study of the vulnerability of the alpine ski industry in the study area (Lynch *et al.*, 1981) concluded that a poor ski season could be as much a problem of perception as a problem of a lack of snow. For example, three main factors influenced the poor ski season in 1979/80: 1) the coincidence of poor skiing conditions with the Christmas holiday break; 2) the perception of poor conditions for the remainder of the season; and, 3) the vulnerability of entrepreneurs to the mild winter conditions. The result was that Blue Mountain Resort had only 25% of its normal staff levels working and had 60% lower revenues, while local ski shops experienced 20-50% lower sales and accommodation bookings declined 10-40% (Collingwood Times, 1980).

Figure 3.1 displays the observed ski season length at a sample of ski areas within the Lakelands study area from the period 1975 to 2000. Horseshoe consistently had the longest ski season, averaging 124 days. In contrast, Sir Sam's, in spite of having several attributes that provide it with a longer potential ski season (*e.g.*, located further north, higher elevation, lower average humidity and north facing ski slopes), had the shortest ski season, averaging only 79 days. While climate is important, the difference in the average ski season at these two ski areas is also related to two other socio-economic factors: 1) their proximity to the City of Toronto (the major market for skiing in the region), and 2) their respective business models. Horseshoe is located within a one-hour drive of the City of Toronto, and situated along a multi-lane expressway. As a result, Horseshoe is able to attract skiers from Toronto who wish to ski for the day and return home in the evening ('day trippers'). Keeping the ski area operational for as long as possible is the business strategy that best allows Horseshoe to capture this demand. In fact, Horseshoe is known for its efforts to be the first ski area to open and the last one to close. Sir Sam's, on the other hand, is approximately a three-hour drive from the City of Toronto, over an hour of which involves using county roads that are prone to poor driving conditions. The greater distance from Toronto means that 'day trips' for skiing are not practical at Sir Sam's ski area. Sir Sam's therefore serves skiers who stay in the area, usually during weekends and holiday periods. During the winter season, Sir Sam's will close mid-week, even though ski conditions may be perfect, because the number of skiers is insufficient.

Table 3.1: Media Depictions of Climatic Vulnerability of Winter Recreation, 1986 to 2001

Winter Season	Date	Headline
1986/87	12/29/86	Ski resorts make new year's wish: more snow
1988/89	01/14/88	Hired ski guns fire with both barrels: Ontario resorts rely on snowmaking machinery to stay afloat
	02/28/89	Operators pouring millions into high risk ski business
1989/90	12/15/89	Early opening a snow job
	02/01/90	Ski resorts get tough with Mother Nature
	03/15/90	Mother Nature delivers blow to ski resorts
1990/91	12/29/90	Cold cash: milder temperatures spell anxious days for ski resorts
1994/95	01/18/95	Worst winter in 30 years for fish hut operators
	01/28/95	Warm weather chills snowmobilers, lack of snow leaves businesses catering to winter enthusiasts out in the cold
	01/29/95	Snowmakers save the day
	02/02/95	Ice thickness varies greatly
1996/97	01/26/97	Copters rescue hundreds stranded while ice fishing: Lake Simcoe airlift goes into night
		Huge ice fishing rescue costs public $300,000
	03/08/97	Let it snow, resort owners pray 25% of season's revenues earned in March break
1998/99	12/13/98	Resorts need to chill out, warm temps killing ski season
	12/13/98	Ski operators hope: let it snow, let it snow
	12/16/98	Resorts sing plaintive chorus for more snow, cold weather: Winter Wonderland it's not
	12/29/98	Cold weather saves season for ski resorts
1999/2000	03/29/00	Ski operators take a big hit
2000/01	12/28/00	Skiing bonanza: snow boosts Ontario
	03/18/01	Blizzard of profits for Ontario resorts
2001/02	12/04/01	Praying for a white Christmas; Warm weather has ski resort operators worried

Two additional findings of interest are illustrated in Figure 3.1. The average ski season in the 1990s was surprisingly as long or longer than the 1970s and 1980s (at four of the five ski areas) even though the winters during the 1990s were on average warmer (the 1990s were the warmest decade in the observational record). Similarly, despite warmer average winters in the 1990s, the standard deviation in the alpine ski seasons declined at three of the ski areas and only increased slightly at the remaining two. A comparison of the impact of the two warmest winters on record exemplifies this point. In the winter of 1982/83 (second warmest winter on record), there is a notable reduction of the ski season at most of the ski areas (including a 44 and 34% decline relative to the previous year at Sir Sam's and Talisman, respectively). Although the winter of 1997/98 was the warmest in the observed record in this region, none of the ski areas experienced as large a negative impact on the ski season length as during 1982/83. The largest reduction was at Talisman, where the ski season was 7% shorter than average. This was not the case further south, as the El Niño winter of 1997/98 had a substantial impact on ski resorts across the US Midwest, reducing business by 50% and causing economic losses estimated at $180 million (Great Lakes Regional Assessment Team, 2000). Analysis of the start date of ski seasons over the same period also revealed no significant trend toward later start dates in the 1990s, although the last three years of the 1990s were among the latest start dates at the ski area of Blue Mountain Resort (Figure 3.2).

The data in Figure 3.1 suggest that ski areas in the Lakelands Region are currently less vulnerable to climate variability than they were in the 1970s and 1980s. The explanation for this reduced vulnerability to climate variability may be found in the substantial investment in snowmaking technology during the 1980s and 1990s (Table 3.2 and see Table 1.7 for a summary of investments). Snowmaking has been used as an adaptation strategy to climate variability by ski areas in the Lakelands Region since the early 1970s. As of 1977, only half of Ontario's ski areas had some type of snowmaking system in place (Coates, 1977 cited in Lynch *et al.*, 1981). Most ski areas did not invest substantially in improvements to snowmaking systems until the mid to late-1980s, in response to the poor ski seasons of 1979/80 and 1982/83. By the mid-1990s, extensive snowmaking systems were in place at all five of the alpine ski areas examined in this study. Before the record warm winter of 1997/98, Blue Mountain had a snowmaking system in place with the capacity to ensure that all 34 of its ski runs could be made operational (from a zero snow condition to a skiable 30 cm base) with two and one-half days of suitable snowmaking temperatures (full capacity is achieved with temperatures at -5ºC or colder). By 1999, Talisman and Horseshoe had developed a similar 'zero snow to full operational capacity' with three and five days, respectively, of suitable snowmaking temperatures.

Analysis of the reported snow depth at the Orillia climate station (natural snow conditions) and at the nearby Horseshoe ski area (natural snow fall plus snowmaking), revealed the importance of snowmaking to the ski industry in the study area. In the years illustrated in Figure 3.3, the absence of snowmaking would have meant that a skiable 30 cm base (solid line in Figure 3.3) would have been achieved for a very short time. Table 3.3 indicates the number of days with a 30 cm base at Horseshoe ski area with and without snowmaking. Results at other ski areas were comparable. The benefit of snowmaking early in the ski season is particularly important. Figure 3.4 illustrates that only through snowmaking has Blue Mountain been able to open the ski season with a minimum 20 cm snow base. The economic viability of the ski areas during these low snowfall

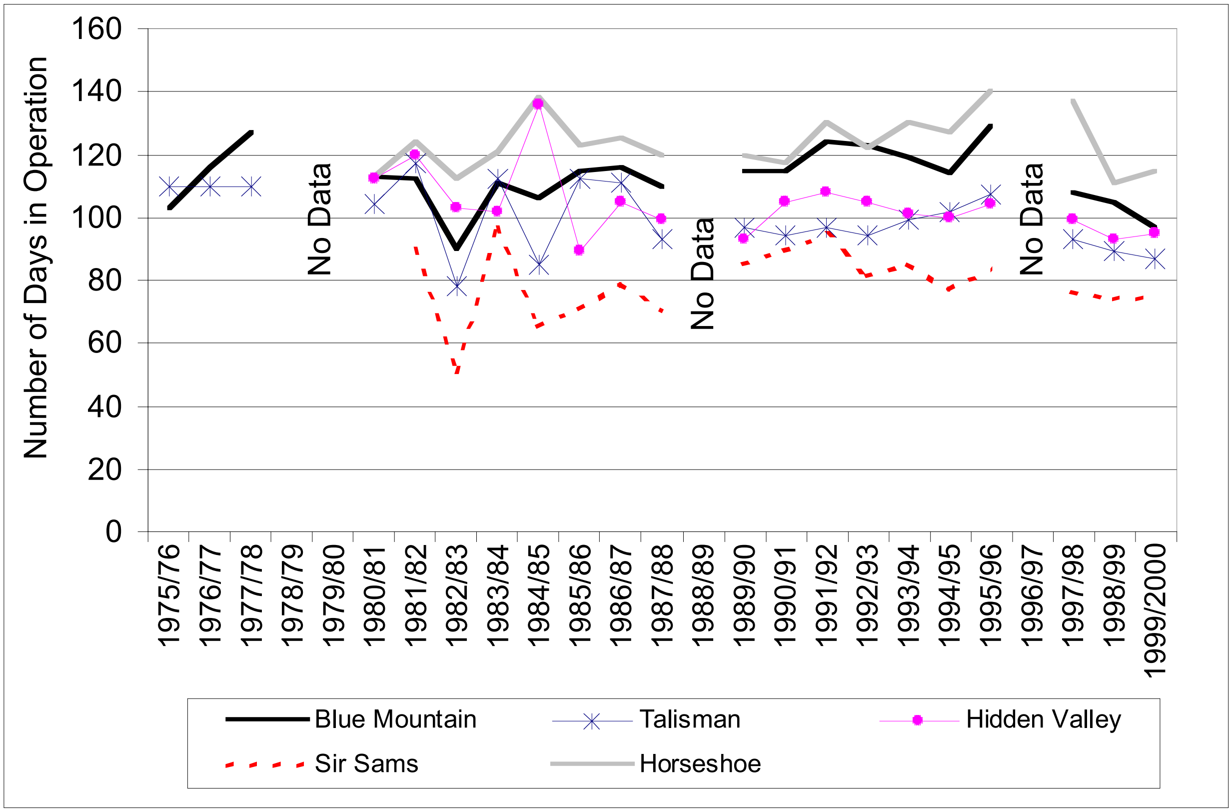


Figure 3.1: Comparison of Observed Alpine Skiing Season Length in the Lakelands Region, 1975/76 to 1999/2000

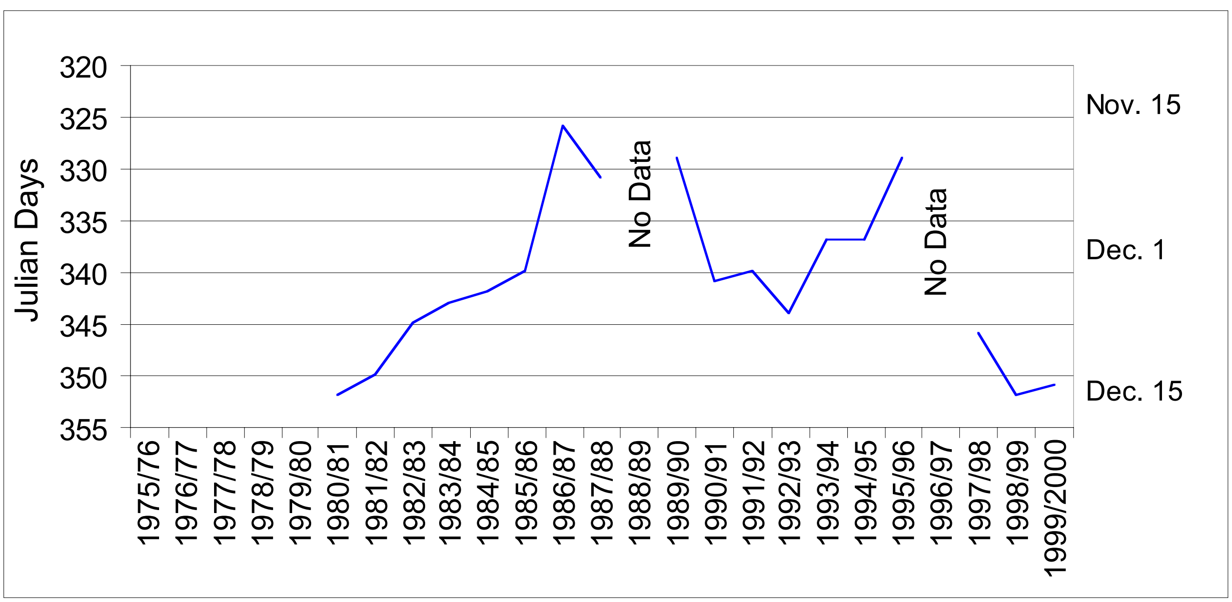


Figure 3.2: Reported Start Date of the Ski Season at Blue Mountain Ski Area, 1975/76 to 1999/2000

Table 3.2: Snowmaking Improvements Undertaken at Ski Areas in the Lakelands Region, 1986 to 2000

	Improvements Undertaken (summer)														
Resort	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**
Horseshoe			✓	✓	✓	✓									✓
Talisman	✓		✓	✓		✓	✓		✓	✓				✓	✓
Blue Mountain	✓		✓	✓		✓	✓		✓	✓					✓
Snow Valley			✓	✓	✓	✓			✓	✓					
Hidden Valley			✓		✓	✓	✓		✓	✓		✓			
Glen Eden			✓	✓		✓	✓		✓	✓		✓	✓	✓	✓
Moonstone	✓		✓		✓	✓	✓			✓					✓

✓ = cited; ✓= inferred

Sources: Skol (1986); MacDonald (1988); Mayers (1988); Skol (1989); Curson (1990, 1991 and 1992); Lebrecht (1994 and 1995); Knowles (2000).

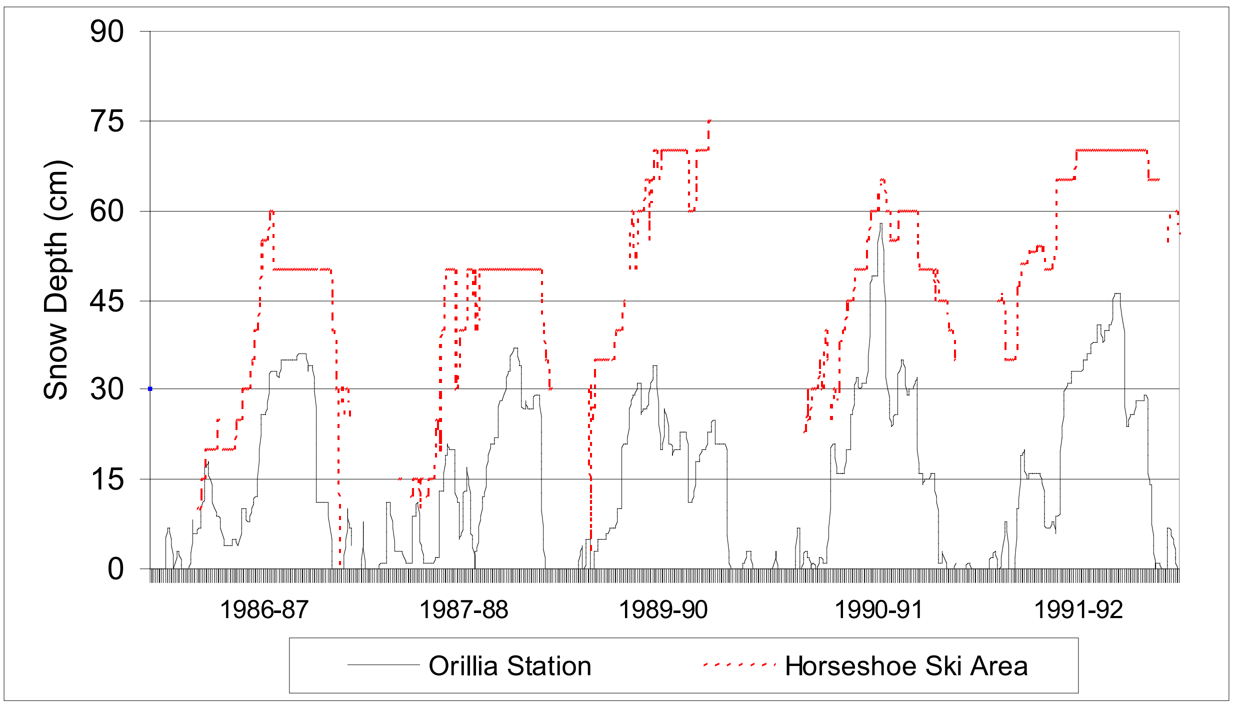


Figure 3.3: Comparative Snow Depth at Orillia Climate Station and Horseshoe Ski Area, 1986/87 to 1991/92

winters would have been questionable without snowmaking systems. As the former director of the OSRA clearly stated (MacDonald, 1988), "If we had to rely on snow from the heavens, the ski industry would be bankrupt." The millions of dollars that the ski industry invested in snowmaking as an adaptation to climate variability more than paid for itself in each of the poor snowfall years identified above. Discussions with ski industry stakeholders confirmed that snowmaking is an integral component of the alpine ski industry in the study area and that the capacity to make snow under climate change conditions is a crucial question for investigation.

A second important adaptation strategy implemented by the larger, well-capitalized ski areas has been diversification from winter resorts to 'all-season' resorts. The two largest ski areas added golf courses, mountain bike trails and other 'green season' recreation activities. Certain ski areas have dropped 'ski resort' from their name to reflect their four-season diversification strategy.

Table 3.3: Number of Days With >30 cm Snow Depth at Horseshoe Ski Area and Orillia Climate Station, 1980/81 to 1995/96

	Orillia Station (natural snow only)	Horseshoe Ski Area (natural snow and snowmaking)	Increased Ski Season (with snowmaking)
1980/81	58	no data	no data
1981/82	63	90	143%
1982/83	42	67	160%
1983/84	48	100	208%
1984/85	63	95	151%
1985/86	no data	no data	no data
1986/87	36	77	214%
1987/88	13	87	669%
1988/89	no data	no data	no data
1989/90	10	92	920%
1990/91	38	111	292%
1991/92	47	130	277%
1992/93	51	112	220%
1993/94	47	109	232%
1994/95	12	112	933%
1995/96	93	128	138%

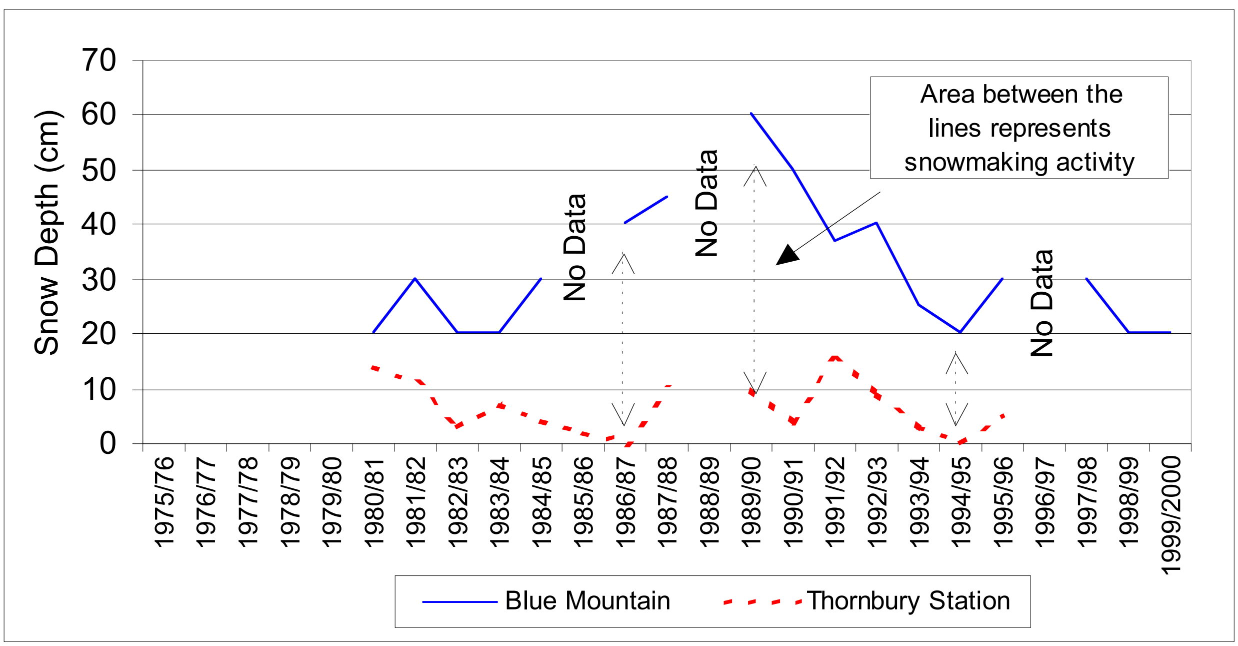


Figure 3.4: Reported Snow Depth at the Start of the Ski Season at Blue Mountain Ski Area, 1980/81 to 1999/2000

Winter Trails - Snowmobiling and Nordic Skiing

Climate variability can have substantial impacts on snowmobiling and the communities that benefit from the winter tourism this recreational industry generates. Inter-annual variability in conditions greatly influences the degree of success or failure for a particular snowmobile club or district. Regional differences can also be pronounced in any given season. The year 1998, for example, provided a wide range of climatic conditions throughout Ontario. In eastern Ontario, the Ice Storm damaged or closed many snowmobile trails. The economic impact to winter tourism-based businesses in the region prompted the Canada-Ontario Business Recovery Assistance Programme to provide $1.5 million to 43 snowmobile clubs in the area to repair the trail system. In the same year, steady and abundant snow resulted in unusually high volumes of snowmobilers in northeastern Ontario. The additional requirements for trail grooming put a strain on the resources of local clubs to maintain the trails. Conversely, OFSC trail permit sales were down in the northwest due to lack of snow (OFSC, 1998).

Although no archived data on snowmobile trail conditions were available for the study area, several sources of anecdotal evidence of climate sensitivity were consulted. Similar to alpine skiing, the media often report on snowmobiling when the recreation season is adversely impacted or when it begins early due to favourable climatic conditions. The poor snow conditions during the winter of 1994/95 adversely affected snowmobiling and related tourism in the Lakelands Region. With the exception of some snow cover in early January, much of the region had insufficient snow depth for grooming snowmobile trails (see Figure 3.5 as an example of the snow cover pattern). An international snowmobile race event (the Georgian Cup) in Owen Sound was cancelled due to the lack of snow. Snowmobile drag races also had to be cancelled in Orillia because of an insufficient ice depth on Lake Simcoe. In 1998/99, the OFSC reported a snowmobiling season of just 10 days near the southern edge of the study area. Conversely, the heavy snowfalls that began in early November provided the same region with a snowmobiling season of over 120 days in the winter of 2000/01. Despite the sensitivity of snowmobiling to climate variability, the industry continues to expand in Ontario and the Lakelands Region.

Unlike alpine skiing where snowmaking can be efficiently concentrated to provide an economical adaptation strategy to climate variability, the linear nature and large distances (often 10s to 100s of kilometres) of snowmobile trails pose a barrier to the widespread implementation of snowmaking systems. Although virtually all snowmobile trails rely exclusively on natural snowfall, the Haliburton Forest and Wildlife Reserve has developed an innovative snowmaking system to provide a more reliable season length and more consistent trail conditions. With this exception, the snowmobiling industry in the Lakelands Region remains reliant on natural snowfall and, unlike the alpine skiing industry, has not been able to reduce its vulnerability to climate variability.

The lengths of Nordic ski seasons within the study area were compiled from the OMTCR database on daily ski conditions (Figure 3.5). The period of archived data covers 14 years during the 1980s and 1990s. Data were available for six Nordic ski areas in the Lakelands Region (Horseshoe, Haliburton Nordic Centre, Duntroon, Mansfield, Hardwood Hills and Muskoka). Like snowmobiling, Nordic skiing trails are almost exclusively reliant on natural snow conditions and thus more sensitive to climate variability than alpine skiing areas. A comparison of the Nordic ski seasons in Figure 3.5 with the alpine ski seasons found in Figure 3.1 (particularly the 1990s) illustrates the greater variability in Nordic skiing seasons in the Lakeland Region. For many of the Nordic ski trails, the longest ski season is more than three times that of the shortest season.

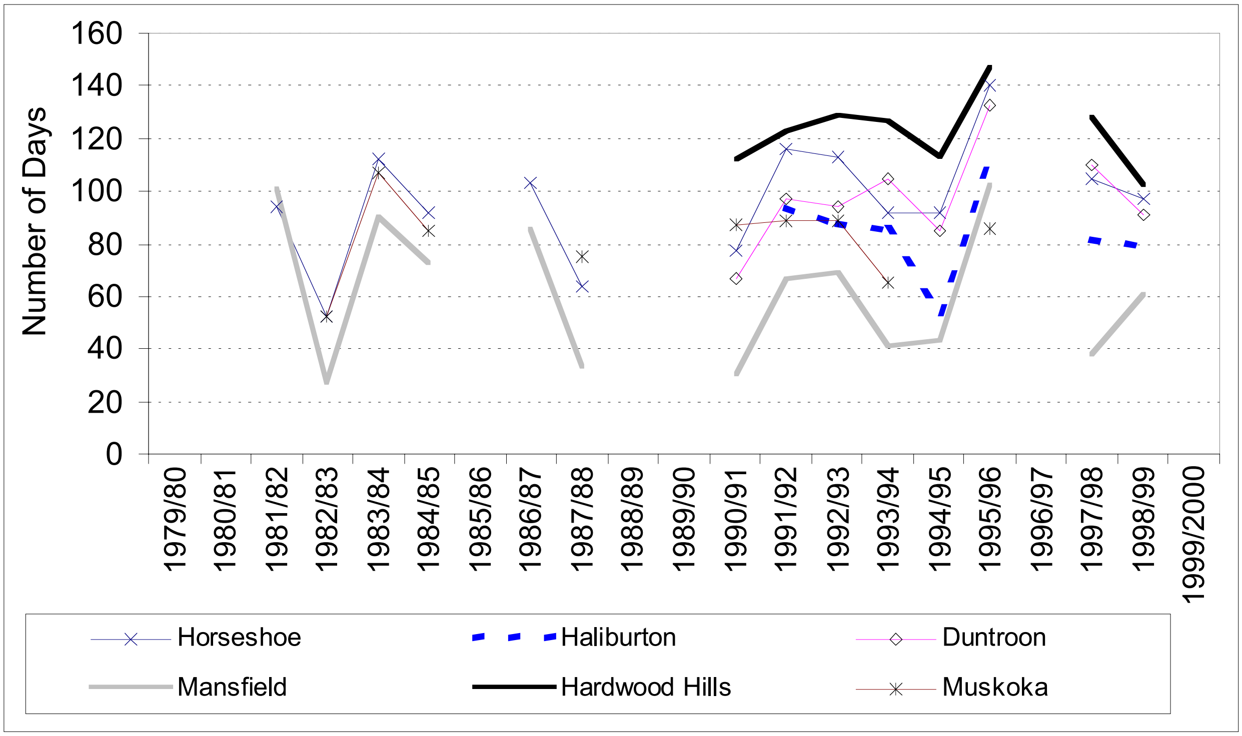


Figure 3.5: Comparison of Observed Nordic Skiing Season Length in the Lakelands Region (1979/80 to 1999/2000)

The shorter distances of Nordic ski trails relative to snowmobile trails makes snowmaking a more feasible technical adaptation strategy.[5] Although some Nordic ski areas have limited snowmaking capabilities (usually only in high traffic, open areas where conditions deteriorate more quickly), only Hardwood Hills has a snowmaking system that covers its entire trail network. Not surprisingly, Hardwood Hills had the longest ski season in every year where data were available. A comparison of reported snow depth at Blue Mountain ski area (Figure 3.4) and nearby Thornbury climate station clearly illustrates the importance of snowmaking for alpine skiing. Without snowmaking, the packed base on alpine ski slopes would be similar to the groomed trail snow depth. Figure 3.4 also illustrates that if demand warranted a longer more consistent Nordic ski season, the implementation of a more comprehensive snowmaking system could make the Nordic ski season at Horseshoe comparable to the much longer alpine skiing season.

Hardwood Hills also provides a good example of another adaptation to climate variability. In addition to implementing snowmaking capabilities, over the past decade the Nordic ski area has diversified to maximize the use of its trail system and support infrastructure throughout the year. Promoting the company's 42 kilometre trail network to mountain bikers has significantly developed the 'green' season. With changes to some trail surfaces and drainage improvements, the transitional period between Nordic skiing and mountain biking lasts less than four weeks.

Ice Fishing

In recent years, ice fishing in the Lakelands Region has been severely impacted by two climate related phenomena: the pressure crack during the 1996/97 winter season on Lake Simcoe, and the shortened ice fishing season during the late 1990s (particularly 1997/98 and 1998/99).

Pressure cracks occur regularly on Lake Simcoe, but rarely cause problems. However, on January 25th, 1997, the location of a crack together with extremely high winds (gusting to 90 km/hr), caused disastrous consequences. Approximately 70 kilometres long and 100 metres wide in some areas, a quick-forming crack stranded ice fishers at several locations on Lake Simcoe (Figure 3.6). Police estimated that nearly 250 people had to be airlifted to safety (Van Rijn, 1997a). Media headlines such as, “Copters rescue hundreds stranded while ice fishing, Lake Simcoe airlift goes into night” and “Huge ice fishing rescue costs public $300,000”, had an adverse impact on the public profile and perceived safety of ice fishing (Van Rijn, 1997b).

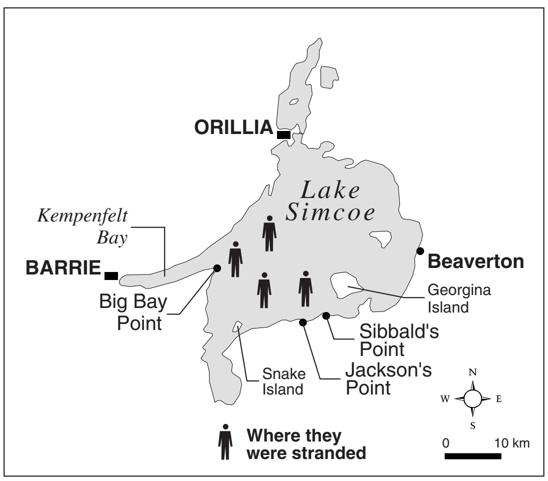


Figure 3.6: The Pressure Crack of 1997 on Lake Simcoe
Source: Van Rijn (1997a)

The frequency and severity of pressure cracks may be increasing on Lake Simcoe, perhaps because of climate variability. As one ice hut operator stated, “The temperature used to be steadier. Now it seems to be a real roller coaster ride” (Jackson’s Point hut operator, 2001).

Warm temperatures also had a major impact on the industry in the late nineties. As indicated, the winter of 1997/98 was the warmest on record in the Great Lakes region (3.7ºC above normal). The winter of 2000/01 was just slightly (0.3ºC) below normal. Contrasting the ice fishing season length at the four locations where data are available for these two years provided an indication of the sensitivity to climate variability. The ice fishing season was between 45 and 64% shorter in 1997/98 than 2000/01 (Table 3.4)[6]. On average, the ice fishing season was reduced by half during the record warm year of 1997/98.

Table 3.4: Variability in Ice Fishing Season Lengths (1997/98 - 2000/01)

	1997/98		1999/00		2000/01
Ice Hut Operator	**Season Length (days)**	**% Change wrt to 2000/01**	**Season Length (days)**	**% Change wrt to 2000/01**	**Season Length (days)**
Midland	45	-46%	50	-40%	82
Jackson's Point	35	-52%	46	-37%	72
Kempenfelt Bay	25	-64%	61	-46%	69
Lake Couchiching	43	-45%	48	-29%	77

wrt: with respect to

In 1997, after 16 years of operation, the town council of Georgina withdrew financial support for the Great Lake Simcoe Ice Fishing Derby. The event usually ran from the fourth week of January to the first week of March. Increasingly unreliable ice conditions were the reason for withdrawing from the event. John Maclean, Director of Leisure Services for the Town of Georgina and a former organizer of the derby, stated (Maclean, 2001), "The fishing derby was designed to be self supporting ... with poor weather two years in a row, you can't continue to gamble with taxpayers money. The weather basically killed it." By 1999, the event was cancelled altogether.

The 1997 pressure crack and warm weather have affected hut operators on Lake Simcoe and elsewhere. "Public paranoia kept people away even though it [the pressure crack] was healed up within a week" (Kempenfelt Bay hut operator, 2001). The poor conditions of the late 1990s resulted in the demise of one ice hut business on Lake Simcoe. "We don't run the business anymore. The big pressure crack scared people off. The locations of the cracks on the Lake are changing and the recent warm years make the ice too unsafe to have clients out there" (former Atherley hut operator, 2001). This ice hut operator was located near the Atherley ice data station, which has the lowest annual ice thickness in the study area. The closure of the ice hut operation in this area is illustrative of how climate sensitivity varies spatially within the study area and may provide an indicator of future impacts in this sector as a result of climate change.

The recreation activities examined in this study are all sensitive to climate variability. The various figures and tables of section 3.1 indicate the level of vulnerability. Alpine skiing, because of its concentration at one location, compared to the linear nature and large distances associated with trail-based activities (Nordic skiing and snowmobiling), has taken greater advantage of snowmaking (Figures 3.3 and 3.4). This has thereby reduced its variability in season length. A comparison of the 1990s with the 1980s in Figure 3.1 illustrates this issue well. The most vulnerable of the activities from year to year is probably ice fishing, being at the whim of temperature, ice thickness and wind field.

Climate Change Impact Assessment

The previous section identified the vulnerability of the four winter recreation sectors to current climate variability and the adaptive strategies used to reduce vulnerability to adverse climate conditions. This section examines how climate change could affect the natural resource base the winter recreation industry is based on and how the vulnerability of alpine skiing and trail-based recreation could change under climate scenarios projected by CGCM1 and HadCM3 (2020s, 2050s and 2080s). For both alpine skiing and trail-based recreation, a detailed analysis of the season length is presented for a single case study site (Horseshoe ski area and Orillia snowmobiling district) to illustrate the type of analysis conducted at each of the seven study area locations. The results for the other four alpine ski areas and six trail locations are then summarized in a table at the end of each section. The discussion of ice fishing impacts concludes the section. The discussion of the analogue year approach used to examine the impacts of climate change on ice fishing season length concludes the section.

Projected Changes in Natural Resources for Winter Recreation

Analysis of the snow regime in the study area revealed important changes under each of the climate change scenarios. Figure 3.7 illustrates that the projected number of days with more than 30 cm snow at Orillia climate station is expected to decline substantially under the CGCM1 and HadCM3 scenarios. In the simulated baseline period (1961-90), the average number of days that snow depth exceeded 30 cm per year was 71.2 days. In the 2020s, the average number of days with 30 cm snow depth ranges from 43.3 days (HadCM3) to only 18.9 days (CGCM1). By the 2080s scenario, snow depth of greater than 30 cm no longer occurs in most years.

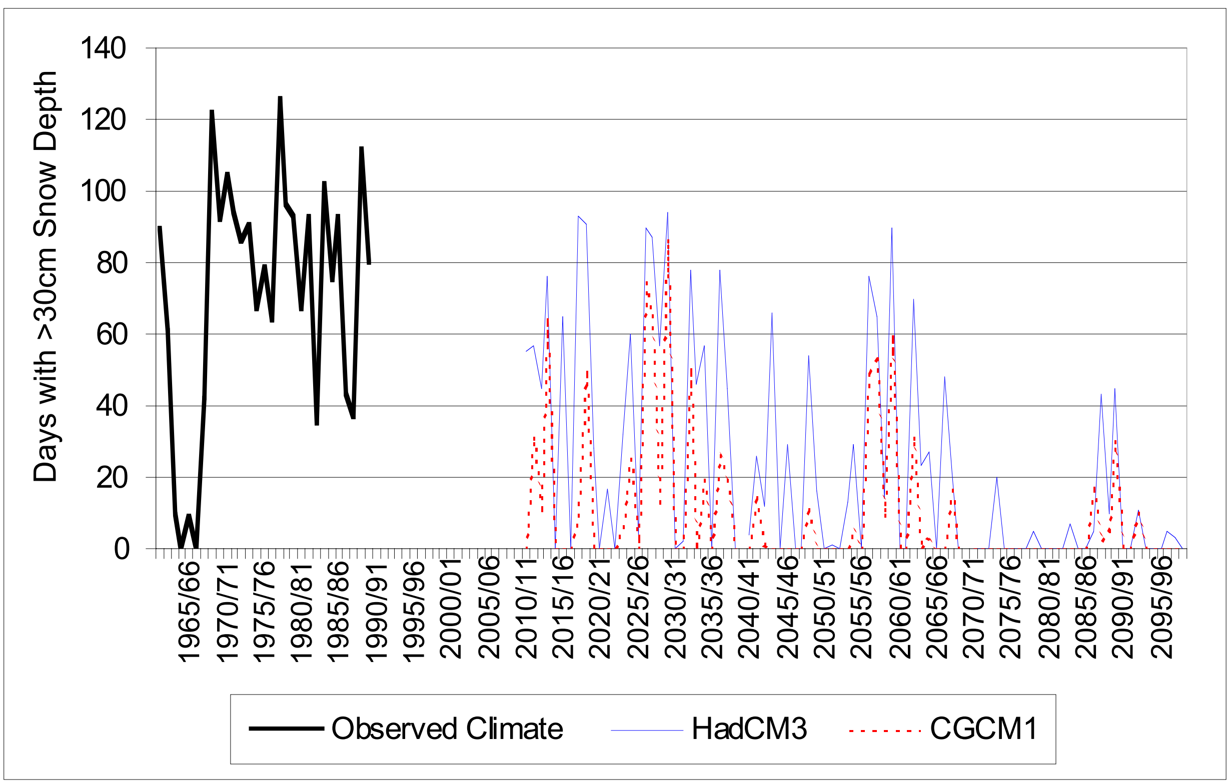


Figure 3.7: Simulated Number of Days With >30cm Snow Base at Orillia Station (1965/66 to 2095/96)

More importantly from the ski industry's perspective are changes in their capability to make snow. The Muskoka climate station is used for illustrative purposes because this location is central within the study area and it is one of Environment Canada's primary climate stations. Figure 3.8 presents the number of observed snowmaking days each year at the Muskoka station from 1961-90 and the simulated snowmaking days from 2010-99. The analogue winter of 1997/98 (the warmest winter on record in this region) is identified as a 'poor year' benchmark for comparison under the CGCM1 and HadCM3 climate change scenarios. In the period 2010-39, a year similar to 1997/98 would be expected to occur once every decade (like the 1990s). However the average number of potential snowmaking days is projected to decline between six (HadCM3) and 11% (CGCM1). The projected loss of potential snowmaking days doubles to between 14 (HadCM3) and 23% (CGCM1) for the 2040-69 time frame (Table 3.5). By this time, the number of snow-making days in 1997/98 becomes the average and in the 2070-99 scenario, a winter similar to 1997/98 would be considered an exceptionally good year.

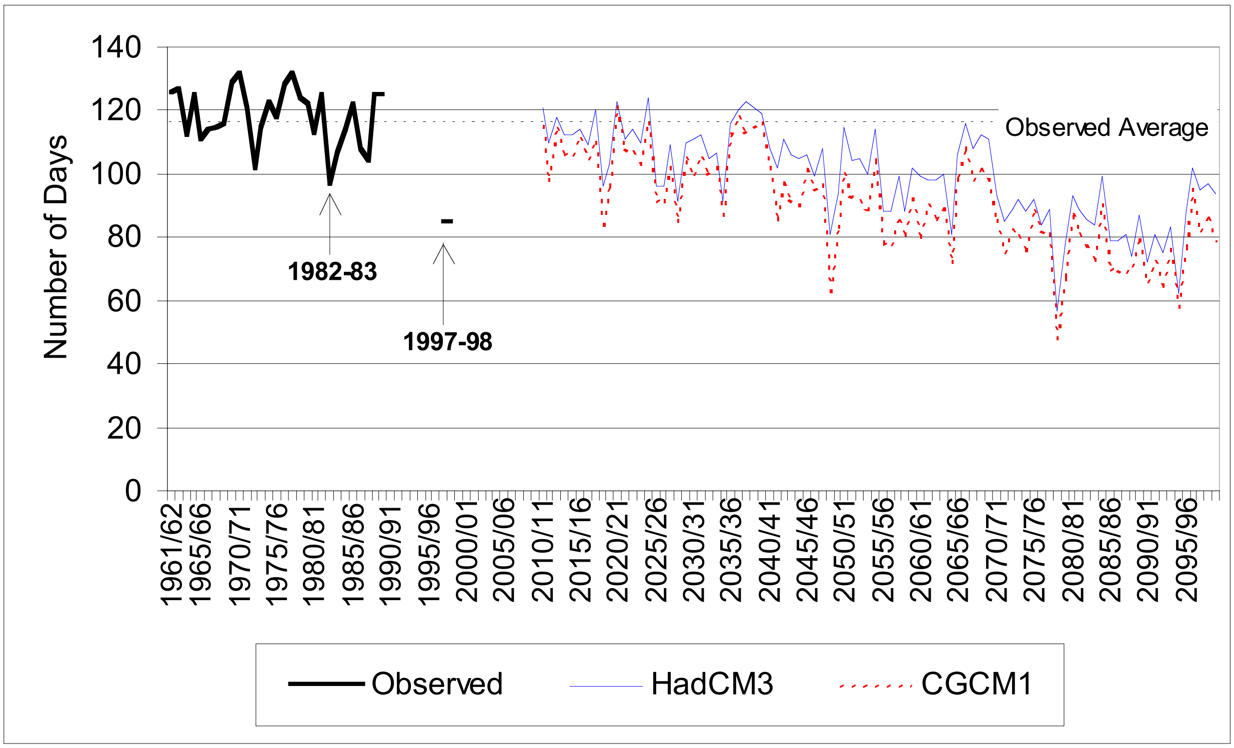


Figure 3.8: Number of Snowmaking Days at Muskoka Station (1961/62 to 2095/96)

In the Lakelands Region, the primary demand for snowmaking is in the early stages of the ski season, and to ensure reasonable skiing conditions during major holiday periods (Christmas and New Year's in late December and Spring Break in mid-March). Further analysis was conducted to determine whether the losses in potential snowmaking days coincided with these periods of peak demand for snowmaking. The temporal distribution of potential snowmaking days (by month) under current and projected climate conditions (Table 3.5) revealed that the early stages of the ski season (late November and December) were not disproportionately affected. Furthermore, when the number of potential snowmaking days in the crucial pre-Christmas period (December 1-20) was assessed (Figure 3.9), the average number of days in the 2020s and even 2050s (under both CGCM1 and HadCM3 scenarios) exceeded those in the analogue winters of 1982/83 and 1997/98.

Table 3.5: Projected Number of Potential* Snowmaking Days at Muskoka Climate Station (1961 - 2080s)

	1961-90	CGCM1 2020s		CGCM1 2050s		CGCM1 2080s	
Nov.	**10.7**	9.4	-12%	7.3	-32%	4.7	-56%
Dec.	**23.5**	22.3	-5%	21.6	-8%	19.8	-16%
Jan.	**27.7**	25.2	-9%	23.1	-17%	22.2	-20%
Feb.	**27.4**	23.0	-16%	19.1	-30%	16.3	-41%
Mar.	**21.1**	18.5	-12%	15.4	-27%	11.6	-45%
Apr.	**7.8**	6.7	-14%	4.5	-42%	1.8	-77%
Total	**118.2**	105.1	-11%	90.9	-23%	76.4	-35%
	1961-90	**HadCM3 2020s**		**HadCM3 2050s**		**HadCM3 2080s**	
Nov.	**10.7**	9.2	-14%	6.9	-36%	4.0	-63%
Dec.	**23.5**	23.1	-2%	21.4	-9%	16.6	-29%
Jan.	**27.7**	27.3	-1%	26.5	-4%	24.2	-13%
Feb.	**27.4**	26.0	-5%	25.2	-8%	22.4	-18%
Mar.	**21.1**	19.0	-10%	16.4	-22%	14.2	-33%
Apr.	**7.8**	6.7	-14%	5.7	-27%	3.5	-55%
Total	**118.2**	111.2	-6%	102.1	-14%	84.9	-28%

*Potential snowmaking days are defined as days with minimum temperature of -5ºC or colder.

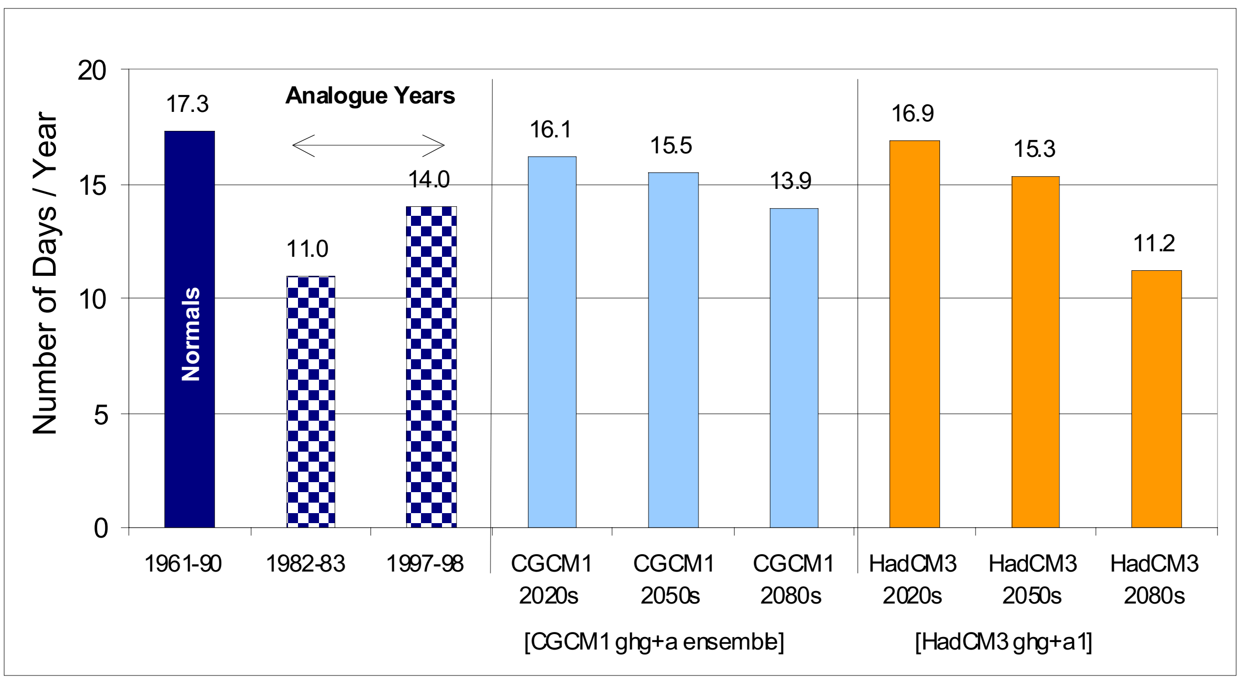


Figure 3.9: Potential Snowmaking Days (Dec. 1-20) (1961 - 2080s)

These results raise questions about the ability of alpine skiing areas to remain operational even with more intensive snowmaking. The snowmaking systems at some ski areas are nearing their temporal capacity (*i.e.*, 'zero snow' condition to fully operational in three days), but this capacity is generally only made use of early in the ski season. In other words, there is much more snowmaking capacity available if it were required more regularly throughout the ski season. If ski areas in the Lakelands Region were able to remain operational in poor snowfall years like 1989/90 and

1994/95 and record warm winters like 1997/98 through intensive snowmaking, then with a comparable number of potential snowmaking days, they could conceivably do so into the 2050s. What remains uncertain is whether the increased level of snowmaking required to remain operational in a warmer climate would be economical. These questions are explored further in the following section.

Alpine Skiing

The findings in this study are consistent with previous climate change impact assessments of the skiing industry in that the scenarios presented suggest an increasingly challenging business environment for the ski industry under climate change. The overall trend at all of the ski areas is toward shorter ski seasons and increased snowmaking costs. The projected impact of climate change on the ski season is substantially different than previous research, because this study has incorporated snowmaking into the impact assessment.

Using the Horseshoe ski area as an example, Figure 3.10 illustrates the simulated ski season length from 1961 to 2099. Unlike previous climate change impact studies of the skiing industry, this analysis was able to examine the impact of climate change scenarios for the early decades of this century (2010-39). This analysis is more relevant to business planning time frames and was well received by stakeholders in the ski industry. The CGCM1 scenario projected a 15% reduction in the average ski season (with respect to the 1961-90 average) in the years 2010-39, while the HadCM3 scenario projected an 8% reduction. Average ski seasons continue to shorten as the magnitude of climate change increases. The CGCM1 scenario projected a 31% reduction during the years 2040-69 and a 47% reduction for 2070-99. Under the HadCM3 scenario, average ski seasons were projected to shorten by 18 and 36% for these respective time frames.

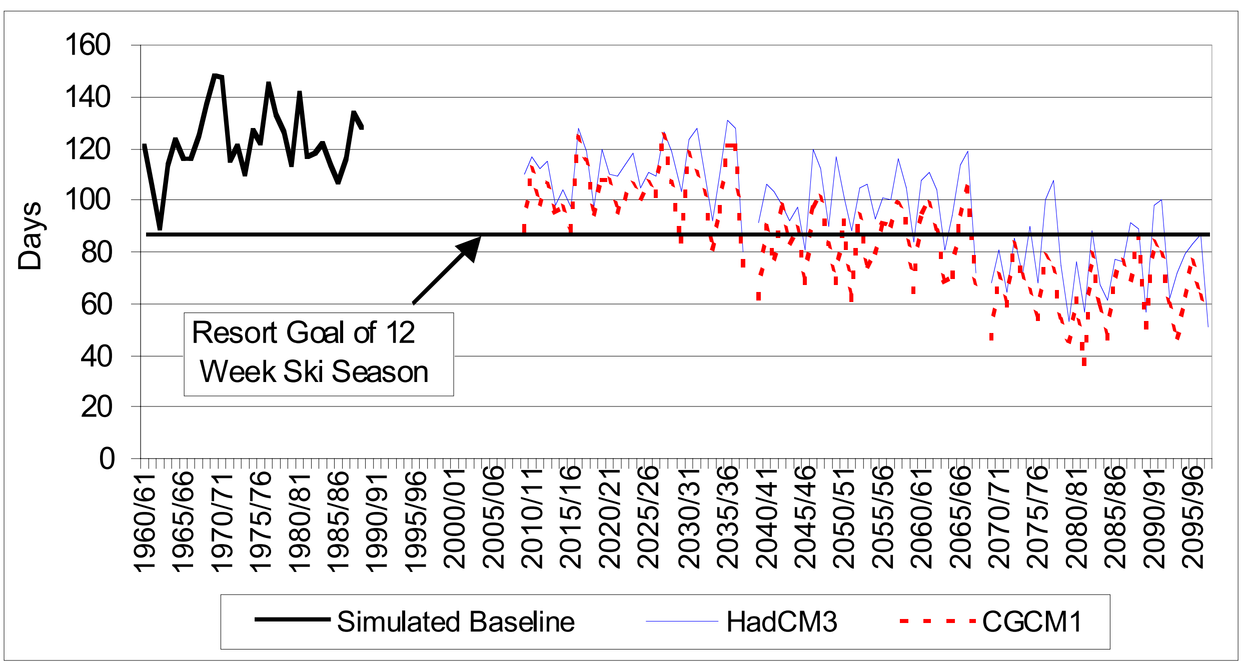


Figure 3.10: Simulated Alpine Skiing Seasons at Horseshoe Ski Area (1960/61 to 2095/96)

When improved snowmaking technology was integrated into the ski season simulation, the length of the ski season at Horseshoe ski area increased in all of the climate change scenarios. Figure 3.11 illustrates the number of days improved snowmaking added to the ski season under the CGCM1 scenario. In the 2020s, improved snowmaking reduced average season losses by 50% (Table 3.7).

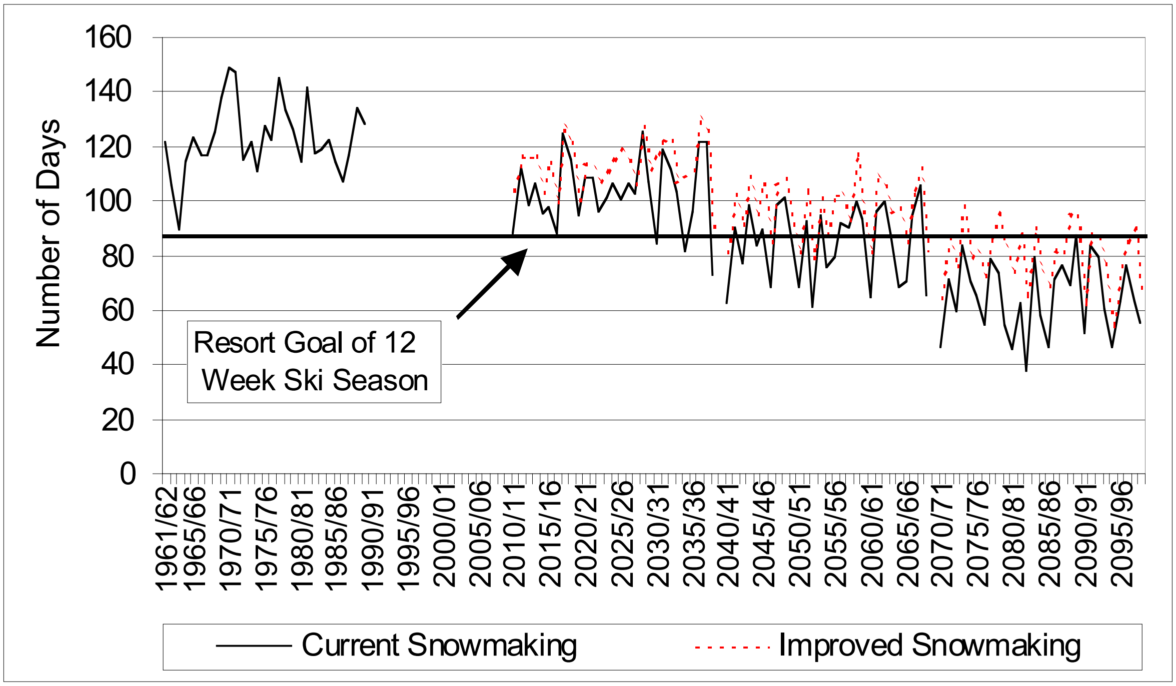


Figure 3.11: Simulated Ski Season Length at Horseshoe Ski Area With Current and Improved Snowmaking Technology (CGCM1 Scenario) (1961/62 to 2095/96)

Figure 3.10 displays whether or not a ski resort achieved the stated business objective of a 12-week season (as indicated by Horseshoe management). During the observed record from 1980-99, this economic benchmark for ski operations was achieved in all years. Similarly, the simulated ski season at Horseshoe indicated the 12-week season threshold was achieved in all years from 1961-99. Both the CGCM1 and HadCM3 climate change scenarios indicate that the average ski season will diminish, posing an increasing challenge to the ability of ski areas to achieve a 12-week ski season. The probability of a 12-week ski season does not change substantially under the 2020s scenarios (Table 3.6). However, by the 2050s, the probability of a 12-week ski season with current snowmaking capacities is 55% under the CGCM1 scenario and 89% under the HadCM2 scenario. With the improved snowmaking technology simulation, the probability improved to 86 and 100%, respectively.

Table 3.6: Probability of a 12-Week Ski Season at Horseshoe Ski Area (1961 to 2080s)

	Current Snowmaking Technology			Improved Snowmaking Technology	
	Current Climate	CGCM1	HadCM3	CGCM1	HadCM3
1961-90	100%				
2020s		93%	100%	100%	100%
2050s		55%	89%	86%	100%
2080s		3%	34%	38%	66%

When the season length projections of all five alpine ski areas in the Lakelands Region were compared, the results consistently indicated a trend toward a shorter average ski season with some variability in the magnitude of change (Table 3.7). The more northerly ski areas that are at higher elevation (Hidden Valley and Sir Sam's) were the least vulnerable to climate change at all three time frames (2020s, 2050s, 2080s). Blue Mountain was the most vulnerable ski area, with average season lengths reduced by 18-30% in the 2020s, 30-52% in the 2050s and 54-66% in the 2080s. This is consistent with its location near the shores of Lake Huron, where lower elevation and the moderating effect of Lake Huron provide a warmer climate that is less conducive to snowmaking. At all ski areas, improved snowmaking would reduce season losses (Table 3.7). Improved snowmaking was most valuable at Blue Mountain, where season losses could be reduced by 10-20% in the 2050s and 2080s. The varied impact of climate change among the five ski areas examined in this study illustrates how climate change could alter the competitive relationships between individual ski resorts. The two more northerly ski areas (Hidden Valley and Sir Sam's) have a climatic advantage that could be further exploited in a conducive business environment.

Table 3.7: Simulated Ski Seasons Under Climate Change Scenarios Using Current and Improved Snowmaking Technology* (1961 to 2080s)

Ski Area & Snowmaking Technology	Simulated Baseline (days)	Change in Season Length CGCM1			HadCM3		
	1961-90	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	125						
Current		-22%	-38%	-54%	-16%	-25%	-40%
Improved		-14%	-26%	-38%	-10%	-17%	-31%
Average							
Current		-19%	-34%	-49%	-12%	-21%	-38%
Improved		-12%	-23%	-36%	-7%	-14%	-28%

* See Table 1.7 for snowmaking technical capacities.

Maintaining the length of ski seasons under increasing climate change will come at a cost, in the form of increased snowmaking. As the trend lines in Figure 3.12 illustrate, the amount of snowmaking (cm) required to achieve ski seasons in Table 3.7 at Horseshoe increases as projected climate change intensifies. Assuming no change in current snowmaking capacities, the amount of snowmaking required at the five alpine ski areas in the 2020s ranges from approximately 150 to 200% of the baseline period; by the 2050s, snowmaking requirements range from 175 to over 300% of baseline. If improved snowmaking technology were implemented to achieve the additional ski seasons gains outlined in Table 3.7; snowmaking requirements would increase further, ranging from 150-280% in the 2020s, 190-410% in the 2050s and 320-510% in the 2080s. Snowmaking is a significant proportion of the annual operating expenses of ski operations in the study area and it remains uncertain as to how such increases would affect profitability of individual ski areas.

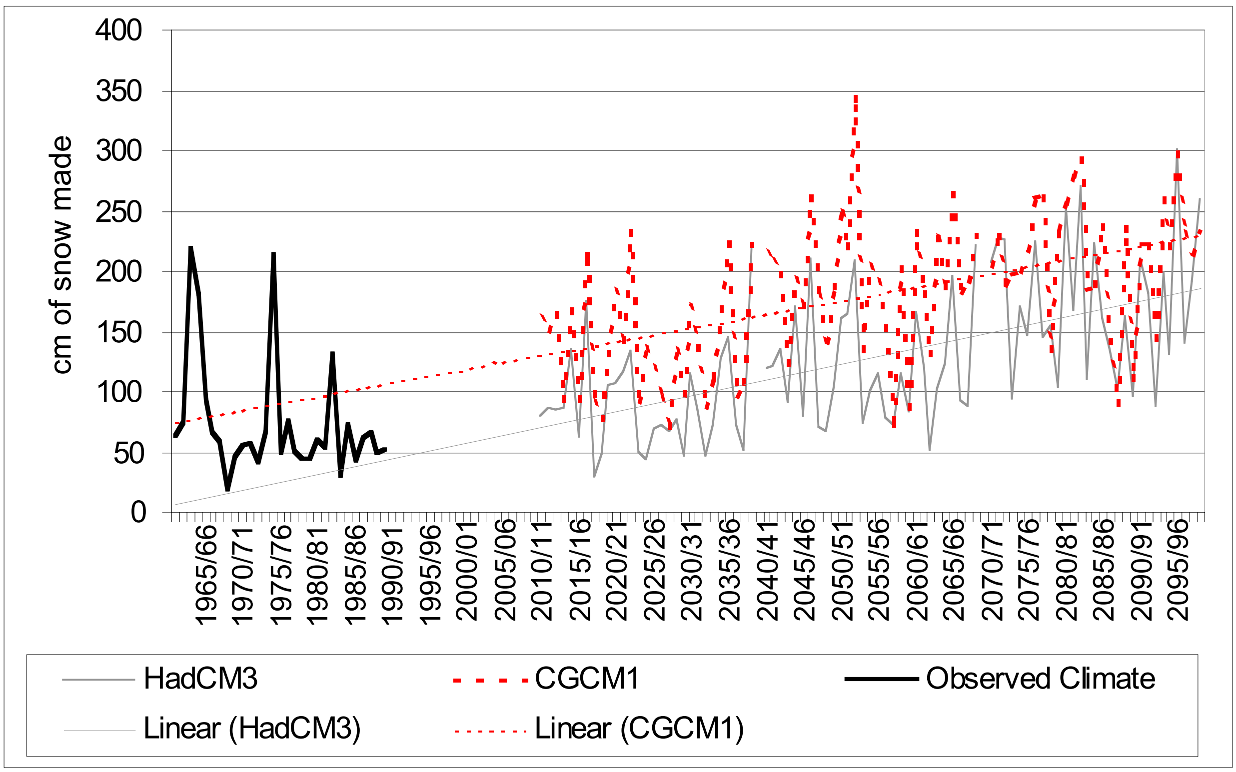


Figure 3.12: Simulated Snowmaking Requirements at Horseshoe Ski Area, 1965/66 to 2095/96

With snowmaking integrated into the climate change impact assessment, the magnitude of the impact of climate change is substantially diminished. In this study, a doubled-atmospheric CO_2 equivalent scenario (~2050s) reduced the average ski season in the study area between 24-52% under the CGCM1 scenario and between 16-30% under the HadCM3 scenario (Table 3.7). These scenarios are more optimistic than earlier studies that estimated a 40-100% loss of the ski season in the region under doubled-CO_2 conditions (McBoyle and Wall, 1992; Ordower, 1995) and clearly demonstrate the importance of climate adaptation. Potential improvements in snowmaking technology could further reduce season losses to between 10-32% under doubled-CO_2 scenarios. This more optimistic scenario must be tempered with the critical uncertainty that the additional costs of snowmaking under warmer conditions may outweigh the economic benefits of an enhanced ski season. Further collaboration between the climate change impact researchers and ski industry stakeholders is required to address this issue.

Winter Trails -Snowmobiling and Nordic Skiing

A previous section indicated that winter trail-based recreation (snowmobiling and Nordic skiing) was more sensitive to current climate variability than alpine skiing, largely because of the adaptation of snowmaking that provides additional snow cover as required to the latter. Consequently, it was anticipated that snowmobiling and Nordic skiing would be impacted to a greater extent by climate change than alpine skiing. The findings in Figures 3.13 and 3.14 confirm that hypothesis.

Figure 3.13 illustrates the snowmobiling season length estimated by the OFSC in the Orillia snowmobile district and the simulated season length using the Crowe'77 climatological thresholds from 1961 to 2099. The average snowmobile season length from 1961-90 was 77 days, near the upper end of the OFSC estimated range. Both the 1961-90 average and the OFSC range are provided as benchmarks to assess the impact of climate change.

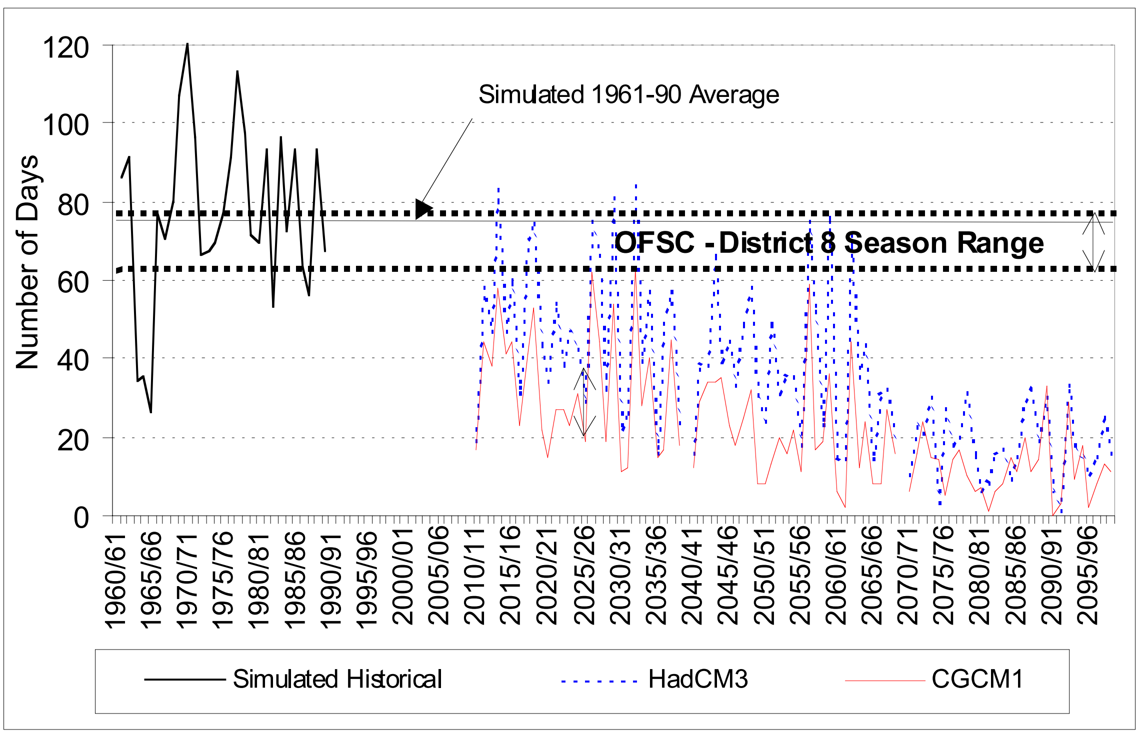


Figure 3.13: Simulated Snowmobiling Season at OFSC District 8 - Orillia, 1960/61 to 2095/96

Both climate change scenarios project substantial reductions in the snowmobile season length in the Orillia district. Even in the 2010-39 CGCM1 scenario, the snowmobile season rarely reaches the lower end of the OFSC estimated historical season range (Figure 3.13) and on average is 54% shorter than the 1961-90 baseline (Table 3.8). The HadCM3 scenario projects 47% for the same time period, and on five occasions reaches or exceeds the 1961-90 baseline average. The 2040-69 timeframe revealed a 77% reduction in average season length under the CGCM1 scenario and a 58% reduction under the HadCM3 scenario. Finally, the longest scenario horizon projected an average season reduction between 80% (HadCM3) and 87% (CGCM1).

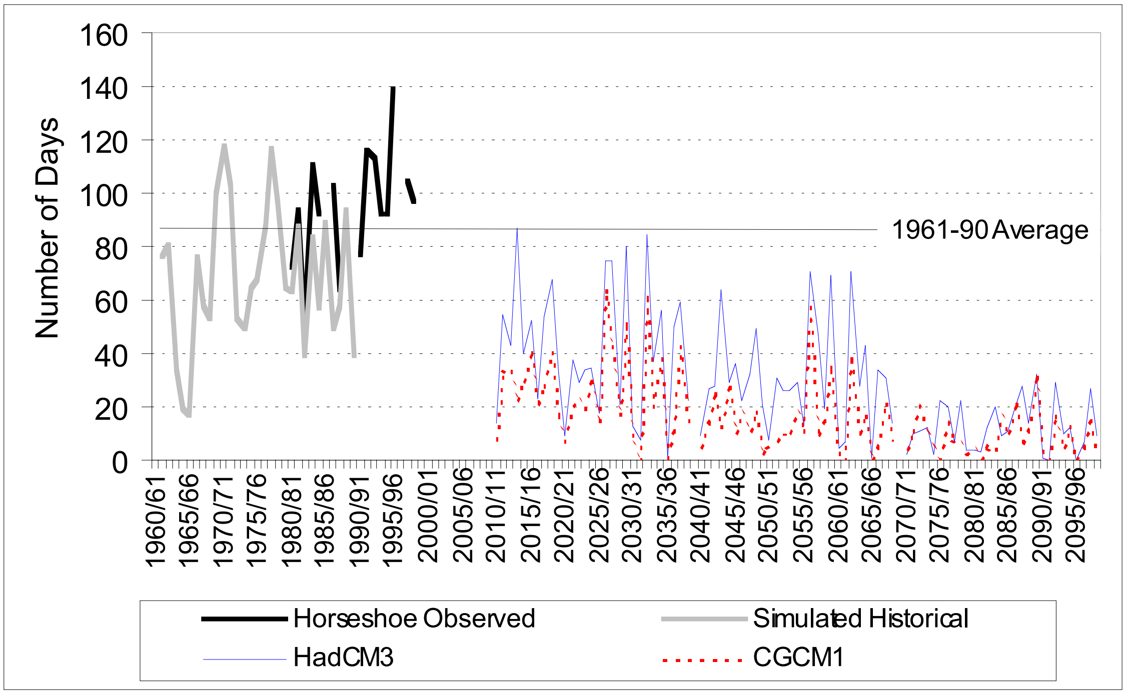


Figure 3.14: Simulated Nordic Skiing Season at Horseshoe and Hardwood Hills, 1960/61 to 2095/96

When the climate change impact scenarios for the seven snowmobiling areas were compared, vulnerability varied spatially. Consistent with climatic theory, snowmobiling areas further north and at higher altitudes (*e.g.*, Haliburton) were projected to experience lesser change (Table 3.8). The average projected reduction in season length at the seven snowmobiling areas is substantial even by the 2020s (ranging from 29 to 49% for the HadCM3 and CGCM1 scenarios, respectively). The average snowmobiling season is projected to be reduced by approximately half at most locations by the 2050s (Table 3.8), with the season further reduced on average between 70% (HadCM3) and 80% (CGCM1) by the 2080s.

Further complicating projections of snowmobiling season length are lake ice cover projections. Long snowmobile trails are often linked by ice-crossings and reduced ice cover and thickness will adversely impact the connectivity of some trail networks. Poor snow conditions on snowmobile trails also encourage some snowmobilers to use lakes instead. This feedback mechanism would increase the exposure of snowmobilers to dangerous ice conditions. In the Lakelands Region, ice cover is projected to decline on average by eight and one-half weeks. While this study identifies marginal ice conditions as an important safety hazard and a consideration for trail connections (which often cross bodies of water), ice conditions have not been incorporated into the analysis of snowmobiling season lengths.

It is difficult to predict whether snowmobilers would continue to invest thousands of dollars in recreational vehicles when the average projected season in the 2050s would be approximately three to five weeks (CGCM1 and HadCM3 scenarios, respectively). The decreased availability of suitable snow conditions could motivate the substitution of one type of recreational vehicle for another that is not limited by snow conditions (*i.e.*, from snowmobiles to ATVs). Similar to snowmobiling, sales of ATVs and participation in this recreational activity had been steadily increasing in Ontario during the 1990s. An experiment by snowmobile and ATV enthusiasts to test the capabilities and recreational experience of ATVs in snow conditions (Taylor, 2000) concluded that when equipped with snow tires, ATVs provide a suitable alternative to snowmobiles. A larger survey of snowmobilers is needed to explore the potential for activity substitution more thoroughly. ATVs are, however, currently banned from snowmobile trails in many parts of Ontario, because they damage the groomed surface prepared for snowmobiles.

Table 3.8: Observed and Simulated Snowmobiling Season Length (days) in the Lakelands Region, 1980 to 2080

Snowmobile Area	Observed 1980-90s Mean	Simulated Seasons (Crowe '77)						
		1961-90	2020s		2050s		2080s	
		Mean	Mean	%△	Mean	%△	Mean	%△
Haliburton (District 6)	91	99						
CGCM1			55	-44%	36	-64%	25	-75%
HadCM3			74	-25%	59	-40%	38	-62%
Huntsville (District 7)	91	98						
CGCM1			54	-45%	37	-62%	24	-76%
HadCM3			75	-23%	61	-38%	34	-65%
Muskoka (District 7)	91	103						
CGCM1			59	-43%	36	-65%	25	-76%
HadCM3			78	-24%	61	-41%	35	-66%
Orillia (District 8)	70	91						
CGCM1			42	-54%	21	-77%	12	-87%
HadCM3			48	-47%	38	-58%	18	-80%
Collingwood (District 8)	70	79						
CGCM1			34	-57%	20	-75%	13	-84%
HadCM3			54	-32%	41	-48%	18	-77%
Chatsworth (District 9)	70	96						
CGCM1			46	-52%	29	-70%	20	-79%
HadCM3			69	-28%	56	-42%	28	-71%
Wiarton (District 9)	70	101						
CGCM1			52	-49%	29	-71%	18	-82%
HadCM3			74	-27%	59	-42%	29	-71%
Average %△								
CGCM1				-49%		-69%		-80%
HadCM3				-29%		-44%		-70%

△ = change

Further development of snowmaking systems for snowmobile trails is another possible adaptation strategy that may receive greater attention in the future. As mentioned earlier, one resort area in the Lakelands Region already uses snowmaking in this capacity. The technical limitations of providing snowmaking to trails networks hundreds of kilometres long and the cost of implementing and operating such systems remain important uncertainties.

Nordic skiing was also found to be more vulnerable to climate change than alpine skiing. The range of average season reduction for the 2010-39 timeframe was 39 (HadCM3) to 55% (CGCM1) (Table 3.9). Only under the HadCM3 scenario did one or two years reach the 1961-90 average season length. The 2040-69 scenario showed even more substantial season losses, ranging from 55 (HadCM3) to 78% (CGCM1). Nordic skiers have less invested in equipment than snowmobilers and therefore substantially reduced season lengths may not have as significant an impact on participation. Without analysis of the behaviour of winter recreation participants during adverse conditions or surveys of how they may react to the shortened season lengths projected under climate change, this possibility remains speculative.

When the climate change impact scenarios for the six Nordic ski areas were compared, vulnerability varied spatially. Consistent with climatic theory, Nordic ski areas further north and at higher altitude (Haliburton) were projected to experience lesser change (Table 3.9). The average projected reduction in season length at the six Nordic ski areas is substantial even by the 2020s (ranging from 39 to 55% for the HadCM3 and CGCM1 scenarios, respectively).

Table 3.9: Observed and Simulated Nordic Ski Season Length (days) in the Lakelands Region, 1980 to 2080s

Nordic Ski Area	Observed 1980-90s Mean	Simulated Seasons (SimXC3) 1961-90 Mean	2020s Mean	2020s % △	2050s Mean	2050s %△	2080s Mean	2080s %△
Horseshoe[1]	65	88						
CGCM1			36	-59%	14	-84%	8	-91%
HadCM3			42	-53%	31	-65%	12	-86%
Haliburton	40	94						
CGCM1			51	-46%	31	-67%	21	-78%
HadCM3			71	-24%	56	-40%	35	-63%
Duntroon	102	73						
CGCM1			29	-60%	16	-78%	10	-86%
HadCM3			51	-30%	37	-49%	14	-81%
Mansfield[1]	62	88						
CGCM1			36	-59%	14	-84%	8	-91%
HadCM3			42	-52%	31	-65%	12	-86%
Hardwood Hills[1,2]	122	88						
CGCM1			36	-59%	14	-84%	8	-91%
HadCM3			42	-52%	31	-65%	12	-86%
Muskoka	49	102						
CGCM1			52	-49%	32	-69%	22	-79%
HadCM3			76	-25%	56	-45%	29	-72%
Average %△								
CGCM1				-55%		-78%		-86%
HadCM3				-39%		-55%		-79%

△ = change

1 Analysis for Horseshoe, Mansfield and Hardwood Hills Nordic ski areas were based on a common climate station and thus the projected season lengths for each climate change scenario was identifical at all three locations.

2 Hardwood Hills is the only Nordic ski area with snowmaking capacity for the entire trail network.

Even in the northernmost areas, the projected Nordic ski season in the 2050s lasts between 31 and 56 days. Most of the Nordic ski areas in the study currently report an average ski season of between 40 and 65 days, so the projected season reductions may not have a substantial impact on the number of users. The two Nordic ski areas that have an average season of over 100 days (Hardwood Hills and Duntroon) are likely to be more vulnerable to climate change. However, the snowmaking capacity at Hardwood Hills would lessen the vulnerability for that operation. By the 2080s, the Nordic skiing season is all but eliminated (-79% HadCM3 to -86% CGCM1) in the southern half of the study area, with the average season lasting only eight to 12 days. As with alpine skiing, these scenarios reinforce the importance of snowmaking as a technical adaptation.

Further development of snowmaking systems represents an obvious adaptation strategy for Nordic skiing areas. Nordic ski trails are substantially shorter than snowmobile trails, which may reduce the technical difficulties and costs associated with this adaptation technology. The presence of snowmaking infrastructure (water supply, pumps, etc.) at alpine skiing resorts, may lead to greater concentration of Nordic skiing in these locales.

Ice Fishing

As indicated previously, the 1997/98 and 1998/99 ice fishing seasons provide analogues for the potential impact of climate change in the Lakelands Region. The winter of 1997/98 was the warmest on record in the Great Lakes region (+3.7ºC above normal); the Lake Simcoe ice fishing season during this winter season was on average (based on four sites) 52% shorter than the winter of 2000/01 (-0.3ºC below normal temperatures). The projected winter temperature change in the CGCM1 2050s scenario is still more than 1ºC warmer (+4.83ºC) than 1997/98, suggesting the ice fishing season would be further reduced. The winter of 1998/99 was 2.7ºC warmer than normal, with an ice fishing season on average (based on five sites) 32% shorter than the winter of 2000/01. The temperature deviation from the 1961-90 normal for 1998/99 is a reasonable analogue for the CGCM1 2020s scenario (+2.97ºC) and slightly higher than the HadCM3 2050s scenario (+2.06ºC).

Considering the ice thickness safety thresholds currently employed by ice hut operators range from 15 to 25 cm (Table 2.8), Fang and Stefan's (1998) ice thickness projections indicate that under average conditions the threshold for safe ice thickness would not be achieved in some locations. The ability of ice hut businesses to operate year-to-year under such conditions would be improbable. It is likely that ice hut operators in areas that currently have the lowest annual ice thickness and shortest ice fishing season will be impacted first, as they will be the first to lose their ability to operate under current safety thresholds. Kempenfelt Bay and Jackson's Point are two such locations. The ice hut operation that went out of business close to the Atherley ice station, an area more susceptible to climate variations, is one example of this type of differential impact.

The combination of shorter than average ice fishing seasons (resulting in fewer fish taken - recall that the fish taken during the two month winter ice fishing season have been estimated to be the equivalent to that taken during the six month open water fishing season) with altered species' ranges and competitive relationships will have different impacts on the need for and type of sport fish stocking at lakes throughout the study area. As there is little replacement of ice fishing with boat fishing during winter months with little ice cover, the reduction of the ice fishing season would benefit fish stocks through reduced fishing pressure. Reduced ice cover would also increase levels of dissolved oxygen and decrease winterkill.

If the ice fishing season is reduced by 50% or more as the analogue years suggest and ice conditions in other key ice fishing regions further south deteriorate to a greater extent, a scenario might occur where there is a net transfer of fishing pressure to the Lakelands Region. For example, if the ice fishing season in the Bay of Quinte region becomes less reliable, ice fishers from that region may travel to Lake Simcoe. This scenario could result in crowding problems, but could also mean that the winter fishing pressure may remain unchanged (or even increase), even though the ice fishing season length has been reduced. Until analysis of the ice fishing season in the Bay of Quinte region is completed, the likelihood of this scenario remains uncertain.

The ice modelling results from the work of Fang and Stefan (1998) indicate that average ice cover and ice thickness will diminish in the study area under climate change. Using the CGCM1 2050s scenario, cumulative days of ice cover will be reduced by as much as 50%, from 120 days to just 60 days. Furthermore, average maximum ice thickness in the region is projected to decline from 50-60 cm to 20-25 cm. The projected ice regime changes have important implications for the ice fishing season, but also for the safety of ice fishers and snowmobilers.

Climate change is also projected to affect the range of fish species in the Great Lakes basin. The impacts compiled by Hofmann *et al.* (1997) are summarized in Table 3.10. While changes in fish species composition have not been incorporated into this analysis of ice fishing, they will have implications for the sport fishery in the Lakelands Region. According to biologists at the Lake Simcoe Fisheries Assessment Unit, there is no longer any natural recruitment of lake trout and spotty recruitment of whitefish in Lake Simcoe (Amtstaetten, 2001). These populations are heavily dependent on stocking by the provincial government.

Table 3.10: Projected Impacts of Climate Change on Fish Species in the Great Lakes Basin

Species	Projected Impacts
smallmouth bass largemouth bass bigmouth buffalo	Northward extension of range
lake trout lake whitefish	Northward contraction of range
brook trout	Contraction of range to stream headwaters Reduced populations due to competition with other trout for remaining habitat
whitefish yellow perch (south) walleye (south)	Decreased populations due to increased egg and larval mortality or inhibited reproduction
alewife yellow perch (north)	Increased populations due to increased reproduction and reduced mortality
lake whitefish northern pike walleye	Decreased sustainable yield

Source: Hofmann et al. (1997).

Meisner (1990) examined the potential loss of thermal habitat for brook trout in two rivers with headwaters at the southern edge of the Lakelands Region. Elevated air and groundwater temperatures reduced the potential thermal habitat in July and August in the two rivers by 30 and 42%, respectively. Minns and Moore (1992) also projected the annual yield capacity of a sample of lakes in eastern Canada would decline for whitefish, northern pike and walleye. Altered survivability under climate change conditions of species being stocked by the OMNR may require stocking programmes to be revised.

Potential Economic Impact of Climate Change

The section on Climate Change Impact Assessment outlined the approach used to estimate the contribution of winter recreation and tourism to the economy of the Lakelands Region. The estimated annual value of each of the four recreational industries in Table 3.11 represents the economic baseline at risk to changes in recreational season length resulting from climate change. Where applicable the estimated economic loss in the Lakelands Region is provided as a range. The range incorporates the average loss based on the various locations in the study area (alpine = five, snowmobiling = seven, Nordic = six) under the two climate change scenarios (CGCM1 and HadCM3) for the 2020s. As indicated in the Economic Analysis section, the estimated losses assume all else remains the same (*i.e.*, no changes within the recreation sector in question and no additional adaptation) and that economic losses are proportional to reduction in season length.

Table 3.11: Economic Impact of Projected Changes to Winter Recreation Season Lengths

Recreational Activity	2020s Economic Baseline (millions)	2020s Projected Reduction in Season Length		Estimated Economic Impact (losses in millions)	
		CGCM1	HadCM3	low range	high range
Alpine Skiing[1]	$172.5 to 221.9				
• Current snowmaking		19%	12%	-	$42.2
• Improved snowmaking		12%	7%	$12.1	-
Snowmobiling[2]	$321.5	49%	29%	$93.2	$157.5
Nordic Skiing[3]	$10.9	55%	39%	$4.2	$6.0
Ice Fishing[4]	$34.2 to 38.2	32%	-	$10.9	$12.2
Total	$538.9 to 592.4			$120.5	$217.9

1. Average of 5 locations
2. Average of 7 locations
3. Average of 6 locations
4. Lake Simcoe only

The multi-million dollar investment in snowmaking by the alpine ski areas in the region has already paid for itself several times over. Under climate change, the value of this adaptation strategy will increase markedly. It is surmised that snowmaking costs will increase in both 2020s scenarios (Figure 3.12) but that the five ski areas will be able to maintain average season lengths similar to those in the 1990s (Table 3.7). Essentially the value of the snowmaking adaptation can be estimated to be the equivalent of the losses prevented (in the tens of millions annually). Although the amount of snow made under the improved snowmaking technology scenario will increase snowmaking costs, the potential annual economic savings from the lengthened ski season are estimated to be $12.1 to $15.5 million under the CGCM1 scenario and $8.6 to $11.1 million under the HadCM3 scenario. An important question for future research to explore is how the need for snowmaking would change (*i.e.*, quantify the volume of snow required and number of days that snowmaking will need to operate) and under what scenario it would no longer be economical.

In contrast to alpine skiing, economic losses related to shortened snowmobiling and Nordic skiing seasons in the 2020s are estimated to be substantial (Table 3.11). The combined economic impact could exceed $100 million (losses of $93.2 to $157.5 for snowmobiling and $4.2 to $6.0 for Nordic skiing).

Using the winter of 1998/99 as an analogue for climate change projected by the CGCM1 2020s scenario, it is anticipated that the average ice fishing season on Lake Simcoe would be 32% shorter than today. The economic impact in the Lakelands region is estimated to be between $10.9 and $12.2 million, with important implications for smaller communities on the east side of the lake, most notably Georgina.

Using the socio-economic and climate change scenarios developed by this study for the 2020s, the cumulative economic losses in the winter recreation sector in the Lakelands region could be in the range of $120.5 to $217.9 million.

CHAPTER FOUR

Conclusions

A number of key findings emerged over the course of the project. The study successfully explored the relative vulnerability of four key winter recreation sectors to current climate variability and climate change. Alpine skiing was the least vulnerable to current climate variability (i.e., had the smallest inter-annual variability in season length), largely as a result of the widespread implementation of snowmaking technology as a technological adaptation. Snowmaking is an integral component of the alpine skiing industry in the study area and in some years extended the ski season by almost 100 days. This multi-million dollar investment has paid for itself several times during mild or low snowfall winters in the 1990s and is expected to prevent losses in the tens of millions of dollars per year under the climate change scenarios examined.

Although the findings in this study are consistent with previous climate change impact assessments of the skiing industry, in that the scenarios presented suggest an increasingly challenging business environment for the ski industry under climate change, the magnitude of the climate change impact is substantially diminished relative to previous studies because the research incorporated snowmaking into the climate change impact assessment. In this study, a doubled-atmospheric CO_2 equivalent scenario (~2050s) reduced the average ski season at the five ski areas between 21 (HadCM3) and 34% (CGCM1) (Table 3.7). These scenarios are more optimistic than earlier studies that estimated a 40 to 100% loss of the ski season in the region under doubled-CO_2 conditions (McBoyle and Wall, 1992, Ordower, 1995), clearly demonstrating the importance of climate adaptation. This more optimistic scenario must be tempered with the critical uncertainty that the additional costs of snowmaking under warmer conditions may outweigh the economic benefits of an enhanced ski season.

The two trail-based winter recreation activities were more vulnerable to current climate variability, with Nordic skiing and snowmobiling seasons reduced by more than 50% in some years. The impact of climate change is also quite pronounced for trail-based recreation activities. Snowmobiling and Nordic skiing activities in the study area could experience a substantial reduction in the average season length (29-49% and 39-55%, respectively) as early as the 2020s (Tables 3.8 and 3.9). Consequently, while the climate change impact assessment research community has largely focused on the vulnerability of the alpine ski industry, the apparent greater vulnerability of the $9.2 billion snowmobile industry in North America (International Snowmobile Manufacturers Association (ISMA) 1999) has been overlooked. Although potential adaptations exist (*e.g.*, implementation of snowmaking, activity substitution - snowmobile to ATV), these strategies would require important changes by recreation suppliers and participants alike. Further investments by government development agencies in trails development for winter tourism should be re-evaluated based on the expected return on investment period and their adaptability for multiple recreational uses. Although snowmaking is widespread in alpine skiing, it still has very limited application in other snow-based winter recreation industries (*e.g.*, snowmobiling and

Nordic skiing) because of technical and economic barriers.

Ice fishing showed a similar vulnerability to climate variability, with the average ice fishing season on Lake Simcoe reduced by approximately 50% during the record warm winter of 1997/98. Ice fishing was the most vulnerable winter recreation activity to climate change. Projected changes in average ice thickness may eliminate safe ice conditions for ice fishing huts in some parts of the study area. Ice fishing as an activity (without the added weight of an ice hut) would persist, but with the average season shortened by an estimated 32% by the 2020s. There is also the potential for increased lake ice hazards for fishers and snowmobilers. Marginal ice conditions could result in more ice fishers falling through the ice, with subsequent increases in attendant rescue requirements and costs. Similarly, there is a potentially dangerous feedback between poor snow conditions and increased lake ice hazard, as some snowmobilers substitute lake ice surfaces for land-based trails when conditions are poor.

A number of additional adaptation strategies were identified that could reduce the projected impacts of climate change. In this study, the potential of improved snowmaking technology to limit season losses in the alpine ski industry was examined. Improved snowmaking reduced average season losses at the five ski areas by 5-7% in the 2020s (Table 3.7), with an estimated annual economic savings of $8.6 to $15.5 million. The benefits of improved snowmaking are much more salient in the 2050s and 2080s climate change scenarios.

Other adaptation strategies can occur in both winter recreational supply and demand. On the supply side, winter recreation trail operations can develop snowmaking systems similar to the alpine skiing industry in order to reduce their vulnerability. Both alpine ski and trail areas can practise 'snow farming' to supplement natural snow and snowmaking. Alpine ski areas can also alter slope design (smooth rough surfaces to reduce snow requirements for safe operations, develop north facing slopes, develop at higher elevations where feasible). A number of recreational suppliers have already diversified by becoming four-season operations offering multiple recreation activities in each season as a means to reduce business sensitivity to climate variability. Additional diversification is possible. For example, alpine ski areas can continue to find innovative uses for ski terrain in the summer. In addition to hiking, a number of dry slope recreation equipment (various wheeled 'mountain boards') have been developed and could be marketed to youth that enjoy snowboarding or skateboarding.

Another important supply side adaptation that operators from all four of the winter recreation sectors should consider strongly is the emerging market for weather derivatives and weather insurance, as a mechanism to reduce their weather-related risk. A weather derivative is essentially a contract between two parties that stipulates what payment will occur as a result of poor meteorological conditions during a specified contract period. Considered highly flexible, weather derivatives can be based on a wide range of meteorological variables (*e.g.*, temperature, precipitation, sunshine, snow and ice conditions) and temporal periods (*e.g.*, a one-week festival or recreational event, weekends during the summer months, ski season, etc.), and can be structured to meet the diverse weather-based risk management needs of a range of economic sectors, including tourism and recreation. For example, a ski area could establish a weather derivative contract based on a specified number of days in December with adequate snowmaking temperatures or amount of snowfall; if meteorological conditions are not met then the ski area would receive financial compensation. More information on the development of the weather derivatives market and existing and potential applications can be found in Conley (1999), Zang (2000) and Dischell (2001).

Adaptation also takes place on the recreation demand side. Our current understanding of demand side adaptation is very limited, as there has been little research into how climate variability affects recreation users' choices regarding recreational activities (whether or not to participate or purchase equipment, activity substitution, use patterns) and destination. In one of the few studies available, Konig (1998a) found that skiers of different skill levels would respond differently to climate change impacts on ski areas in Australia. Half of high-skill skiers indicated they would travel to other locations in the world for quality ski conditions. Only 18% of low-skill skiers would incur the expense of international travel to ski and an almost equal number (16%) indicated they would give up skiing altogether if the impact scenario provided to them occurred.

This study is the first of its kind and advances climate change impact assessment in the tourism and recreation sector in a number of ways. The research is the first Canadian study to do the following: assess the vulnerability of winter recreation activities to current climate variability over multiple-seasons; quantify the importance of snowmaking as an adaptation strategy for current climate variability; and, fully integrate snowmaking into the climate change impact assessment. The study is also the first (Canadian or international) to examine multiple recreation industries in the same region, moving closer to the completion of the first integrated sectoral assessment in the tourism and recreation field. It is also believed to be the first study (Canadian or international) to assess the validity of recreation-climatology thresholds with observed recreation data, in an attempt to calibrate climate change simulations. The research is the first climate change impact assessment in the tourism and recreation sector to use the most recent generation of GCMs and assess potential impacts over three time frames (2020s, 2050s, 2080s). The construction of socio-economic and climate change scenarios for a common time-frame (2020s) is also an important development. It is hoped that the new methodological approach developed here will improve climate change impact assessment in the tourism and recreation sector in other areas of Canada and the US.

A number of areas for further inquiry also emerged during the course of the research. As mentioned, the current understanding of how recreational users and tourists adapt to climate variability is very limited. Additional research building on Adams (1973), König (1998a) and Braun *et al.* (1999) is needed. In order to understand the net potential impact of climate change on the tourism and recreation sector of the Lakelands Region, the summer portion of the integrated sectoral assessment would need to be completed. Equally, to understand the impact of climate change on the winter recreation industries in the Lakelands Region, the impacts of climate change on neighbouring winter recreation destinations will need to be examined. For example, the varied impact of climate change among the five ski areas examined in this study illustrates how climate change could alter the competitive relationships between individual ski resorts. This is equally true of competitive relationships between larger ski regions. If the magnitude of climate change impacts in Québec and the northeastern United States is such that more Ontario skiers stay within the province, the market share of the Lakelands' ski areas may increase despite slightly reduced ski seasons. Better socio-economic scenarios and testing of the snowmaking module used in this study are needed, but require the collaboration of recreation and tourism operators. Winter recreation activities are intuitively at risk to a warmer climate and like previous research in the field, the research team encountered some resistance to the study. Over the course of this study the research team also experienced excellent co-operation from many stakeholders. The fact that financial institutions had mentioned climate change in the context of financing discussions with some alpine ski operators might help to explain increased interest in the research and is illustrative of why the tourism industry needs to consider the implications of climate change more seriously. The emergence of the weather derivative market to reduce weather-related business risk may also signal a more short-term need to better understand the vulnerability of winter recreation and tourism to climate variability, and facilitate greater collaboration between industry stakeholders and applied climatologists.

End Notes:

[1]All dollar amounts are Canadian and were converted using an exchange rate of 1.5246, the value of the Canadian dollar according to the Bank of Canada, 2 June 2001.

[2]Active skiers are defined by the CSC as those who ski more than six times annually and are 12 years of age or older.

[3]An angler day is defined as all or part of any day on which an angler fished for recreation (DFO, 1997).

[4]Canadian Climate Archive is maintained by the Meteorological Service of Canada (MSC) (1999b).

[5]Although nordic skiing can occur with less snow depth than snowmobiling, the requirements for groomed trails are similar to that for snowmobiling.

[6]With only four years of data, length of an ice fishing season in a colder than normal year (and thus the full range of ice fishing seasons under current climate conditions) remains uncertain.

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Appendices

Appendix A - Tourism and Recreation Sector Stakeholders Consulted

Steve Berry Haliburton County Snowmobile Association Haliburton, Ontario	Jack Lynch Ontario Ministry of Tourism Barrie, Ontario
Steve Berry Royal Homes Minden Minden, Ontario	Margot Minardi Ontario Snow Resorts Association Collingwood, Ontario
Peter Berry Health Canada Ottawa, Ontario	Barrie Martin Ontario Ministry of Natural Resources Haliburton, Ontario
Bob Bishop Sir Sam's Ski Area Haliburton, Ontario	Chris Milner Ontario Ministry of Tourism Bracebridge, Ontario
Peter Brogden Frost Centre Haliburton, Ontario	Brent Ongman North York Ski Centre North York, Ontario
Andy Campbell Haliburton County Development Corporation Haliburton, Ontario	Kevin O'Rourke Ontario Federation of Snowmobile Clubs Barrie, Ontario
Randy Clark Muskoka Chamber of Commerce Muskoka, Ontario	Pelmorex (Weather Network) Mississauga, Ontario
Mike Dureau Etobicoke Centennial Park Ski Centre Etobicoke, Ontario	Martha Perkins Haliburton Echo Haliburton, Ontario
Kate Evans Haliburton Snowmobile Club Haliburton, Ontario	Bobby Picard Haliburton County Snowmobile Association Haliburton, Ontario
Martin Fearry Haliburton County Haliburton, Ontario	Peter Rigby Haliburton Chamber of Commerce Minden, Ontario
Stephen Foster Federation of Ontario Cottager Association Toronto, Ontario	Paul Samson Ministry of Economic Development and Trade Kitchener, Ontario
Dan Gage Nordic Trails Association Haliburton, Ontario	Peter Schleifenbaum Haliburton Forest and Wildlife Reserve Haliburton, Ontario
Michael Garneau Canadian Council of Snowmobile Organizations Barrie, Ontario	Toronto Star Newsroom Toronto, Ontario
K-W Record Sports Department Kitchener, Ontario	Min Yan Ontario Ministry of Tourism, Culture and Recreation Toronto, Ontario
Nicole Leeper Ontario Ministry of Tourism, Culture and Recreation Toronto, Ontario	

Appendix B - Ice Fishing Industry Interview Protocol

Operator Name:________________________________

Operator Location:______________________________

1. What are the thresholds that you follow for setting out and retrieving ice huts from the lake? Insurance companies? Government?

2. What climate factors either increase or prohibit ice fishing?

3. If ice fishing is not available do people engage in clear water fishing as a substitute?

4. What is the ice variation like on your lake or area?

5. Do you have records of when ice huts were put on and taken off the lake?

6. Who is your market?

7. How would the lack of an ice-fishing season impact your business?

8. Would you like to participate in a more detailed study?