Assessing the vulnerability of the alpine skiing industry in Lakelands Tourism Region of Ontario, Canada to climate variability and change

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Abstract

The vulnerability of the alpine ski industry to climate variability and projected climate change is assessed in the Lakeland Tourism Region of south-central Ontario, Canada. A 17-year record of daily ski conditions at five ski areas was used to examine sensitivity to climate variability and the impact of snowmaking as a climate adaptation. Historical ski data were also used to calibrate a model to simulate the length of ski season under climate change scenarios (2020s, 2050s, 2080s) from the CGCM1 and HadCM3 general circulation models (GCMs). The LARS weather generator was parameterized to local climate stations and used to temporally downscale climate variables from the GCMs for input into a daily snow cover simulation model. A snowmaking module was developed using decision rules and capacities from the study area and integrated with the snow cover model. Analysis was also undertaken with improved snowmaking capacities, in order to account for the potential of further technological advances. The increased development of snowmaking throughout the 1980s and 1990s was found to have reduced the vulnerability of the ski industry. Under climate change scenarios and current snowmaking technology, the average ski season at the five ski areas was reduced by 8-30% in the 2020s, 16-52% in the 2050s and 30-66% in the 2080s. Concurrent with the ski season losses, the estimated amount of snowmaking required doubled at most locations by the 2050s. With improved snowmaking technology and additional snowmaking, ski season losses could be reduced to 3-17% in the 2020s, 10-32% in the 2050s and 22-49% in the 2080s. The climate change analysis revealed the differential vulnerability of the five ski areas, how snowmaking costs are expected to increase at each location, and the relative benefits of improved snowmaking. The ability of individual ski areas to absorb additional snowmaking costs and remain economically viable remains an important avenue of further research.

Key Words Climate Change, Winter Tourism, Skiing

Introduction

Weather and climate have a strong influence on the tourism and recreation sector (Paul 1972, Perry 1997), including the physical resources that are the foundation of many recreation activities (e.g., water levels for boating and snow cover for skiing) and the length and quality of tourism and recreation seasons. Nonetheless, 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 climate variability has not been adequately assessed. Despite the growing significance of the tourism industry to the global economy (World Tourism Organization 1998), Wall (1992) and Smith (1990) expressed concern that current understanding of the potentially profound impacts of global climate change on this sector remained equally limited.

The winter tourism industry in particular has been repeatedly identified as potentially vulnerable to climate change (ACACIA 2000, IPCC 2001, Agnew and Viner 2001) and has received greater research attention. Climate change impact assessments of ski areas in a number of nations (Australia – Galloway 1988, Konig 1998; Austria – Breiling et al. 1997; Canada – McBoyle and Wall 1992; Scotland – Harrison et al. 1999; Switzerland – Konig and Abegg 1997) all project negative consequences for the industry. One limitation of these studies has been the incomplete consideration of snowmaking as a climate adaptation strategy. Snowmaking is an integral component of the ski industry (Konig 1998, Scott et al. 2002) and must be incorporated into climate change impact assessments.

The objectives of this study are (1) to assess the current climate sensitivity and adaptation of the ski industry in the Lakelands Tourism Region of Ontario, Canada, and (2) to develop and apply a research methodology capable of integrating both current and improved snowmaking capabilities into a climate change impact assessment of the industry (2020s, 2050s, and 2080s).

Material and Methods

Study Area

The Lakelands Tourism Region in south-central Ontario, Canada was selected as the case study because of the importance of the tourism sector to the local economy (the direct and indirect economic contribution of tourism was CDN$814 million and over 26,000 full-time equivalent jobs in 1999), its importance as a key recreation destination for Canada's largest urban centre (the Greater Toronto Area) and the concentration of winter recreation infrastructure. Southern Ontario is home to 30% of Canada's active alpine skiers (Canadian Ski Council 2000) and the ski areas in the region function as a nursery for the more challenging vacation ski resorts of North America and beyond (McBoyle and Wall, 1992). The estimated economic impact of the ski industry in the study area ranges from CDN$62 to $93 million (Scott et al. 2002) and in part represents what is at risk to climate change.

Data

The analysis focused on five ski areas in the study area (Table 1). Data on the daily ski conditions (including whether the ski area was in operation, snow depth, snow conditions, ski runs open, and snow making activities) for the winters of 1981-82 to 1999-2000 was provided by the Ontario Ministry of Tourism, Culture and Recreation. The selection of climate stations for this study was based on two considerations, the proximity to ski areas and the length of record and data quality at individual climate stations. Table 1 identifies the climate stations used in this study and the nearby ski areas they represent. Daily temperature (maximum, minimum and

Table 1 Ski areas and corresponding climate stations in the study area

Ski Area	Skiable Hectares	Number of Runs	Nearest Climate Station	Lat	Long	Elevation (masl)	T & P Record	Snow Depth Record
Hidden Valley	18	11	Huntsville	45.2^0	79.13^0	286	1961-99	1961-96
Sir Sam's	16	12	Haliburton	45^0	78.35^0	320	1965-92	1961-92
Horseshoe	25	22	Orillia	44.37^0	79.25^0	220	1961-99	1961-96
Blue Mountain	102	34	Collingwood-Owen Sound	44.29^0	80.13^0	221	1961-99	1961-96
Talisman	202	18	Chatsworth	44.24^0	80.54^0	305	1961-99	1961-96

mean), precipitation (rain and snowfall) and snow depth data were obtained from the Meteorological Service of Canada. In all cases, a complete record for 1961 to 1996 (the last year the rehabilitated snow depth data set was available) was developed. The climate change scenarios used in this analysis were obtained from the Canadian Climate Impact Scenarios (CCIS) project. The scenarios provided by CCIS have been constructed using recognised methodologies and in accordance with the recommendations of the Intergovernmental Panel on Climate Change's (IPCC) Task Group on Scenarios for Climate Impact Assessment. The scenarios are derived from thirty-year means (2010-2039 corresponding to the 2020s scenario, 2040-2069 to the 2050s scenario and 2070-2099 to the 2080s scenario), and represent change with respect to the 1961-1990 modelled baseline period. Data from six modelling centres were obtained for the area $43\text{-}46^0$N by $79\text{-}82^0$W (including between 4 and 6 GCM grid boxes). 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 analysis, as they represented close to the upper and lower bounds of climate change scenario for the study area (Scott et al. 2002). The IS92a greenhouse gas plus aerosol ensemble scenarios (gax) were used in each case.

Methods

The climate data set at each of the five locations consisted of five variables (maximum, minimum and mean daily temperature, precipitation, and snow depth) and was constructed in several stages. Temperature and precipitation data for the baseline period (1961-90) were compiled from climate station data. To produce daily temperature and precipitation data for each of the climate change time series (2010-2039, 2040-2069 and 2070-2099), monthly climate change scenarios from CGCM1 and HadCM3 were temporally downscaled using the LARS stochastic weather generator (Semenov et al. 1998), parameterized to each of the five local climate stations. Temperature and precipitation variables were used to drive a locally calibrated snow cover model that was based largely on methods used to develop the *Canadian Daily Snow Depth Database* (Brown et al. 1999) and *Water Balance Tabulations for Canadian Climate Stations* (Johnstone and Louie 1983). The validity of the approach was tested using observed data from the 1980-90 period at two primary climate stations in the area (Muskoka and Wiarton). The performance of the snow cover model versus observed snow depth at the Muskoka station is presented in Figure 1. To complete the climate data set, a snowmaking module was appended to the snow cover model. 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. Anticipating technological improvements in snowmaking systems, the study also parameterized a snowmaking module with improved capacities (Table 2).

Table 2 Snowmaking module technical capacities and decision rules

	Current Snowmaking Technology	Improved Snowmaking Technology
Technical Capacity		
▪ minimum temperature for efficient snowmaking	-5^{0}C	-2^{0}C
▪ snowmaking capacity / day over entire skiable terrain of ski area	10cm	15cm
Snowmaking Decision Rules		
▪ snowmaking window	Nov. 23-March 30	Nov. 23-March 30
▪ snow base depth to maintain	50cm	50cm

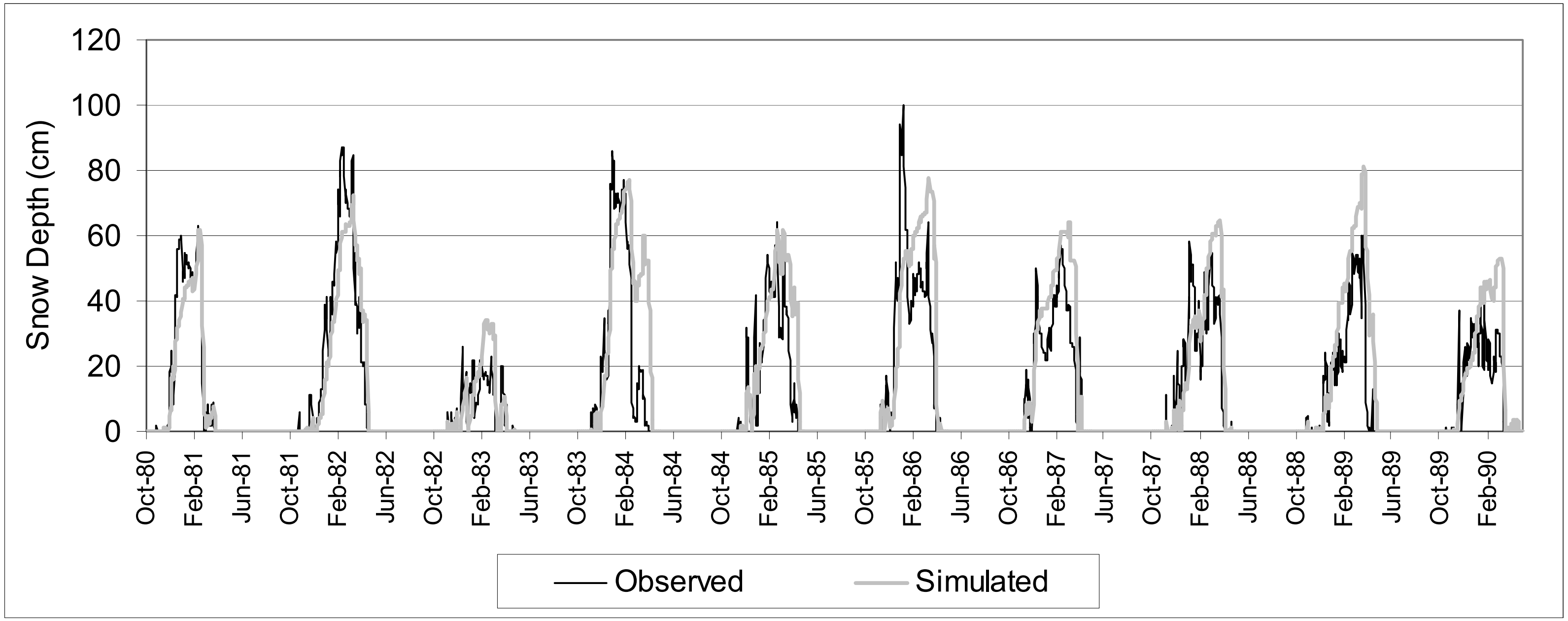

Figure 1 Observed and simulated snow depth at Muskoka climate station 1980-1990. The Muskoka climate station is used for illustrative purposes because it is one of Environment Canada's primary climate stations and it is centrally located within the study area.

A number of climatological thresholds that define a 'skiable day' were identified in a literature review (Crowe et al. 1973, Period and Lamothe 1988). After comparing the thresholds against observed ski conditions and ski area operational activity in the study area, it was determined that these thresholds were unsatisfactory for simulating ski seasons in the study area (Scott et al. 2002). In some cases, snow depth thresholds were unrealistic and dismissed (e.g., 2.5cm in Crowe et al. 1973). The thresholds for minimum and maximum temperature and precipitation were also exceeded frequently in the observed data. This is in part explained by the different decision making of skiers (demand) and ski area management (supply). The former may chose not to ski when it is very cold or during poor snow conditions, but the latter must open to generate business revenue and accommodate those willing to accept sub-optimal conditions. The climate thresholds used to parameterize the ski season simulation model in this analysis were refined through examination of the observed ski operations data and communications with ski industry stakeholders. For the purposes of this study, ski areas were assumed to be closed if any of the following conditions occurred: snow depth < 30cm, maximum temperature > 10^0C for two consecutive days while accompanied by liquid precipitation, or when two-day liquid precipitation > 20 mm. A comparison of the observed and simulated 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). Overall the ski season simulation performed reasonably, missing the observed season length by more than seven days (approximately 5% of an average season) in only 5 of 17 years.

Results

Current Climate Sensitivity and Adaptation

Figure 2 displays the observed ski season length at the five ski areas within the study area from 1975 to 2000. Horseshoe consistently had the longest ski season averaging 124 days. Sir Sam's ski area had the shortest ski season with an average of only 79 days. This is in spite of having several attributes that provide it with a longer potential ski season (located further north, higher elevation, lower average humidity, and north facing ski slopes). The difference in the average ski season at these two ski areas is related to their respective business models. Horseshoe is located within a one-hour drive of Toronto, and situated along a multi-lane expressway. As a result, Horseshoe resort is able to attract skiers from Toronto who wish to ski for the day and return home in the evening (day trips). Keeping the ski area operational for as long as possible is the business strategy that best allows the Horseshoe resort to capture this demand. In contrast, Sir Sam's ski area is approximately a three-hour drive from Toronto. The greater distance and more variable travelling conditions mean 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 in mid-week, even though ski conditions may be perfect, because the number of skiers is insufficient to offset operating costs.

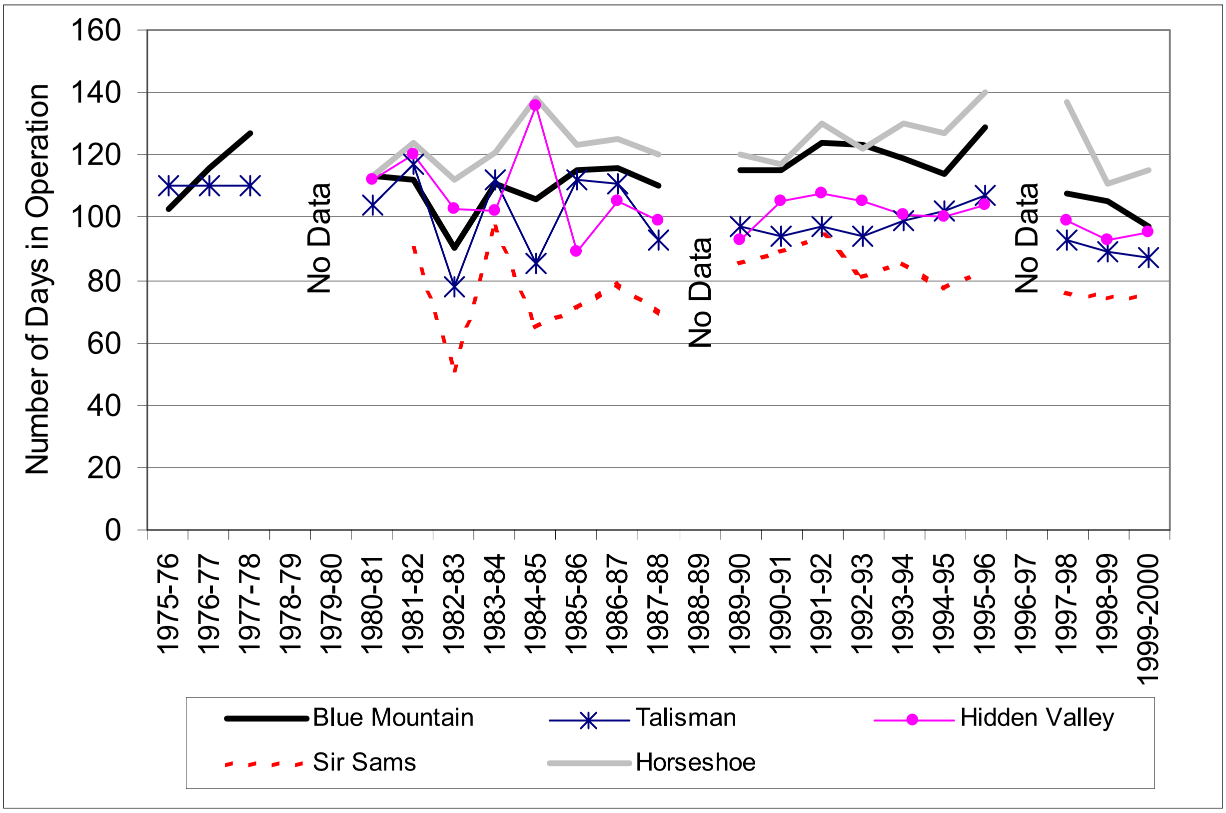

Figure 2 Inter-resort comparison of observed alpine skiing season length

The average ski season in the region during the 1990s equalled or exceeded that in the 1970s and 80s, even though the winters during the 1990s were on average warmer (the 1990s were the warmest decade in the observational record). Similarly, despite warmer winters, the variability in the ski seasons at all five ski areas declined in the 1990s. 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 was a notable reduction of the ski season at most of the ski areas. 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. Poor ski conditions and the shortened ski season may still have resulted in a greater economic impact in 1997/98, but annual economic data for the ski industry in the study area are not available.

The explanation for this reduced vulnerability to climate variability may be found in the multi-million dollar investment in snowmaking technology. As of 1977, only half of Ontario's ski areas had some type of snowmaking system in place (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. Both Blue Mountain and Talisman ski areas have sufficient snowmaking capacity to make all of their ski runs operational (from a zero snow condition to a ski-able 30 cm base) with three days of suitable snowmaking temperatures. Four of the five ski areas have 100% snowmaking coverage of skiable areas.

The importance of snowmaking to the ski industry in the study area is revealed clearly in Figure 3, where the recorded natural snow depth at the Orillia climate station is compared with the reported snow depth at the nearby Horseshoe ski area (natural snow fall plus snowmaking). In the years illustrated, the absence of snowmaking would have meant that a skiable 30cm base (solid line in Figure 3) would have been achieved for a very short time. Snowmaking extended the skiing season at the Horseshoe ski area by 33% to 830% during the 1980s and 90s. Results at other ski areas were comparable. The economic viability of the ski areas during these low snowfall winters would have been questionable without snowmaking systems. The estimated CDN$10 million that the ski industry invested in snowmaking during the late 1980s and early 1990s as an adaptation to climate variability (Scott et al. 2002) more than paid for itself in each of the poor snowfall years identified above.

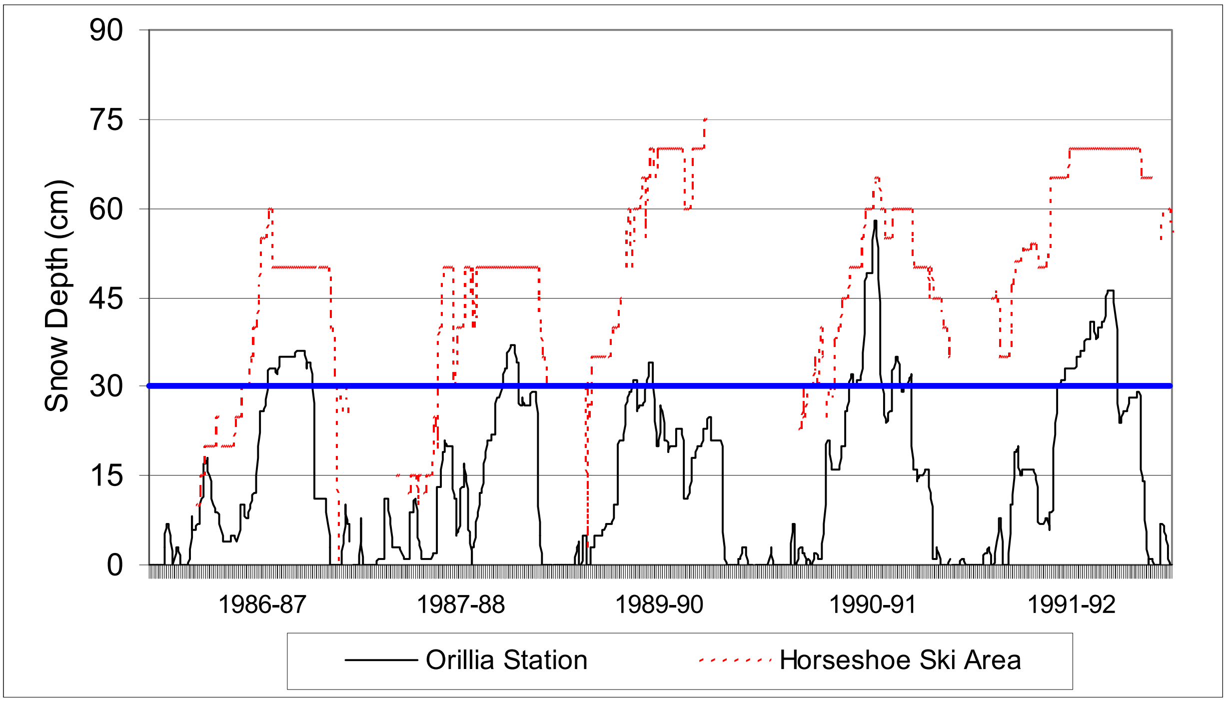

Figure 3 Comparative snow depth at Orillia climate station and Horseshoe ski area. Ski areas in the study area cite a 30cm snow base (solid line) as preferred for ski operations.

Climate Change Impact Assessment

Analysis of the snow regime in the study area (days with snow cover and days with >30cm snow depth) revealed important changes under each of the climate change scenarios. Figure 4 illustrates the number of days with >30cm snow at Orillia climate station under the CGCM1 and HadCM3 scenarios without snowmaking. More importantly from the ski industry 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. Table 3 indicates the number of potential snowmaking days at the Muskoka station from 1961-90 and the simulated potential snowmaking days from 2010 to 2099 under both CGCM1 and HadCM3 scenarios. Using the number of potential snowmaking days from the warmest winter on record in this region (1997/98) as an analogue, such a year would be expected to occur once every decade in the 2010s-30s. The average number of potential snowmaking days in the 2010-39 period is projected to decline

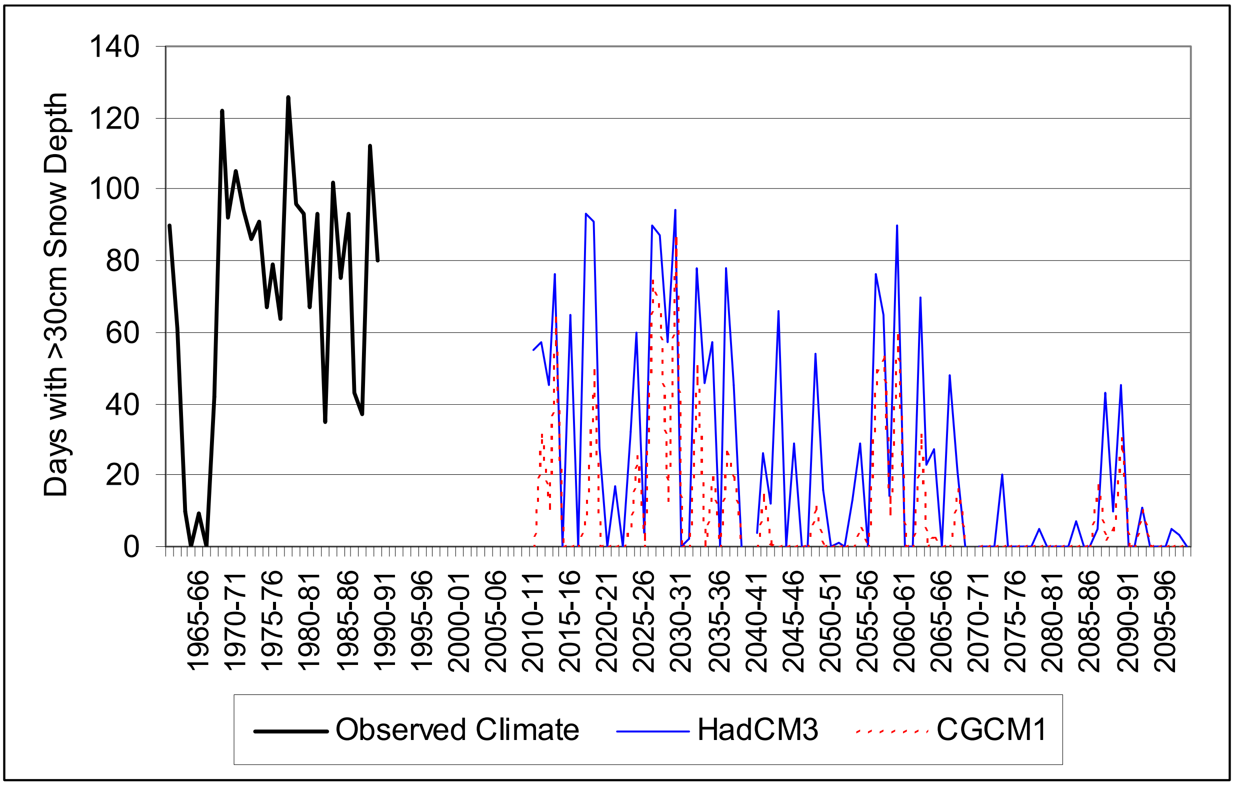

Figure 4 Simulated number of days with >30cm snow base at Orillia station

between 6% (HadCM3) and 11% (CGCM1). The projected loss of snowmaking days doubles to between 14% (HadCM3) and 23% (CGCM1) for the 2040-69 time frame. By this time, the winter of 1997/98 becomes the average and in the 2070-99 scenarios, a winter similar to 1997/98 would be considered an exceptionally good year for snowmaking.

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 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) revealed that the early stages of the ski season (late November and December) were not disproportionately affected. Furthermore, when

Table 3 Projected number of potential snowmaking days at Muskoka climate station. Potential snowmaking days are defined as days with minimum temperature of -5^0C or colder.

	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%
March	21.1	18.5	-12%	15.4	-27%	11.6	-45%
April	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%
March	21.1	19.0	-10%	16.4	-22%	14.2	-33%
April	7.8	6.7	-14%	5.7	-27%	3.5	-55%
Total	118.2	111.2	-6%	102.1	-14%	84.9	-28%

the number of potential snowmaking days in the crucial pre-Christmas period (December 1-20) was assessed, the average number of days in the 2020s and even 2050s (under both CGCM1 and HadCM3 scenarios) exceeded those in the analogue winter of 1997/98.

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), which are more relevant to business planning time frames. Again using the Horseshoe ski area as an example, Figure 5 illustrates that average ski seasons continue to shorten as the magnitude of climate change increases. The CGCM1 scenario projected a 15% reduction in the average ski season (wrt the 1961-90 average) in the years 2010-39, while the HadCM3 scenario projected an 8% reduction. 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 5 also displays whether or not a ski season achieved the stated business objective of a 12-week season (as indicated by Horseshoe management). During the observed record from 1980-

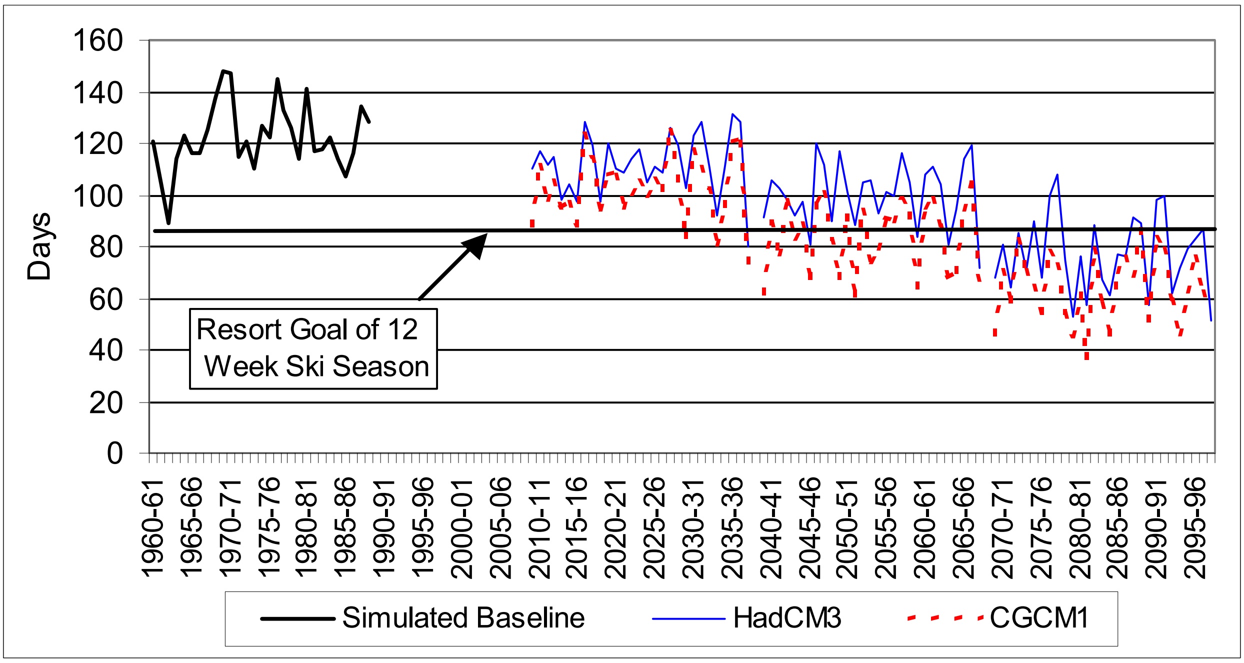

Figure 5 Simulated ski season at Horseshoe ski area

99, this economic benchmark was achieved every year. 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.

When the season length projections for the five alpine ski areas in the Lakelands region were compared, the results consistently indicated an overall trend toward a shorter average ski season with some variability in the magnitude of change (Table 4). The more northerly ski areas that are at higher elevation (Sir Sam's and Hidden Valley) were the least sensitive to climate change at all three time frames (2020s, 50s, 80s). 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 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 4).

Improved snowmaking was most valuable at Blue Mountain, where season losses could be reduced by 10-20% in the 2050s and 2080s.

Maintaining the length of ski seasons under increasing climate change will come at a cost, in the form of increased snowmaking. Assuming no change in current snowmaking capacities, the amount of snowmaking required 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 ski seasons gains indicated in Table 4, snowmaking requirements would increase further, ranging from 150-280% in the 2020s, 190-410% in the 2050s and 320-510% in the 2080s.

Table 4 Simulated ski seasons under climate change scenarios using current and improved snowmaking technology. See Table 2 for snowmaking technical capacities.

Ski Area & Snowmaking Technology	Simulated Baseline (days) 1961-90	Change in Season Length CGCM1 2020s	2050s	2080s	HadCM3 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%

Conclusion

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 study advances the field by incorporating snowmaking as a climate adaptation into the climate change impact assessment. When snowmaking is included in the analysis, 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. 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. Furthermore, the impact of climate change on skiing demand is another area requiring further research.

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 (Sir Sam's and Hidden Valley) have a climatic advantage that could be further exploited in a conducive business environment. This is equally true of competitive relationships between larger ski regions. If the magnitude of climate change impacts in Quebec and the Northeastern United States are such that more Ontario skiers stay within the province, the market share of Lakelands ski areas may increase despite slightly reduced ski seasons. Further analysis of the potential impact of climate change on the major ski areas of North America is required for insight into the potential economic impact of climate change for the ski industry and winter tourism patterns.

Acknowledgements

The authors are grateful to all the tourism and recreation sector stakeholders who gave time and insight to the project and the Government of Canada's Climate Change Action Fund for partially funding the project. The authors would also like to thank the Ontario Ministry of Tourism for the provision of ski conditions data, Elaine Barrow (Environment Canada) for climate change scenario data, Mikhail Semenov (University of Bristol) for the use of the LARS-Weather Generator, and Brenda Jones, Chris Lemieux, Ryan Schwartz, and Stephen Svenson for data collection and entry (all at the Faculty of Environmental Studies, University of Waterloo).

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