16A.2 A REASSESSMENT OF CLIMATE CHANGE AND THE SKIING INDUSTRY IN SOUTHERN ONTARIO
(CANADA): EXPLORING TECHNICAL ADAPTIVE CAPACITY

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1. INTRODUCTION

Weather and climate have a strong influence on the tourism and recreation sector. In some regions, climate is the resource on which the tourism industry is predicated and in others has a major influence on the physical resources that are the foundation of tourism (e.g., health of coral reefs, water levels for boating, snow cover for skiing). Despite the growing significance of the tourism industry to the global economy, comparatively few investigations have assessed the relationships between climate and tourism and recreation (Smith 1993, Perry 1997, de Freitas 2001). As a consequence, the vulnerability of individual recreation industries and tourism regions to climate variability and global climate change has not been adequately assessed.

The winter tourism industry in particular, has been repeatedly identified as potentially vulnerable to climate change (Wall 1992, ACACIA 2000, IPCC 2001) and has received greater research attention. Climate change impact assessments of ski areas in a number of nations (Australia, Austria, Canada, Scotland, Switzerland, and the United States) all project negative consequences for the industry. An important limitation of previous studies has been the incomplete consideration of snowmaking as a climate adaptation strategy. Snowmaking is an integral component of the ski industry in North America and this study examined how current and improved snowmaking capacity affects the vulnerability of the ski industry in Southern Ontario (Canada) to climate variability and change.

2. METHODOLOGY

A schematic for the study methodology is provided in Figure 1, with the data sources and methodological procedures utilized outlined sequentially below.

Data on daily ski conditions (including whether the ski area was in operation, snow depth, snow conditions, number of ski runs open, and snowmaking activities) for the winters of 1981-82 to 1999-2000 was obtained from the Ontario Ministry of Tourism, Culture and Recreation for a primary ski area (Horseshoe Resort) in the study

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region. This data was used to calibrate a ski season simulation model that included a snowmaking module with climatic thresholds and operational decision rules based on interviews with ski area managers.

A complete record of daily temperature (maximum, minimum and mean), precipitation (rain and snowfall) and snow depth data for 1961 to 1996 (the last year the rehabilitated snow data set was available) was obtained from the Meteorological Service of Canada for the Orillia climate station (44.37°N-79.25°W, 220 masl).

Monthly climate change scenarios from six modelling centres (using between four and six General Circulation Model [GCM] grid boxes depending on the resolution of the model) and forced with both IS92a and SRES emission scenarios (as available) were obtained for the study area. In order to consider a wide range of possible climate futures, yet limit the number of scenarios used in the analysis to a manageable number, scenarios that represented the upper and lower bounds of change in December-January-February (DJF) mean temperatures and precipitation were selected.

To produce daily temperature and precipitation data for each of the climate change time series (2010-2039 corresponding to the 2020s scenario, 2040-2069 to the 2050s scenario and 2070-2099 to the 2080s scenario), monthly climate change scenarios from the six selected GCM scenarios were downscaled using the LARS stochastic weather generator (Semenov et al. 1998), parameterized to the Orillia climate station using climate data from the baseline period 1961-90.

Temperature and precipitation variables obtained from the LARS-WG were used to drive a locally calibrated snow depth model that was 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). This technique involved estimating three parameters: 1) amount of precipitation that falls as snow and rain, 2) snow accumulation, and 3) snowmelt. A constant snowpack density of $300 kgm^{-3}$ was assumed (after Brown and Braaten 1999) and a US Army Corps of Engineers (1956) equation used for daily snowmelt calculations.

To complete the ski area snow conditions modelling component, a snowmaking module was integrated with the snow depth model. The estimated technical capacities (e.g., minimum temperature at which snow
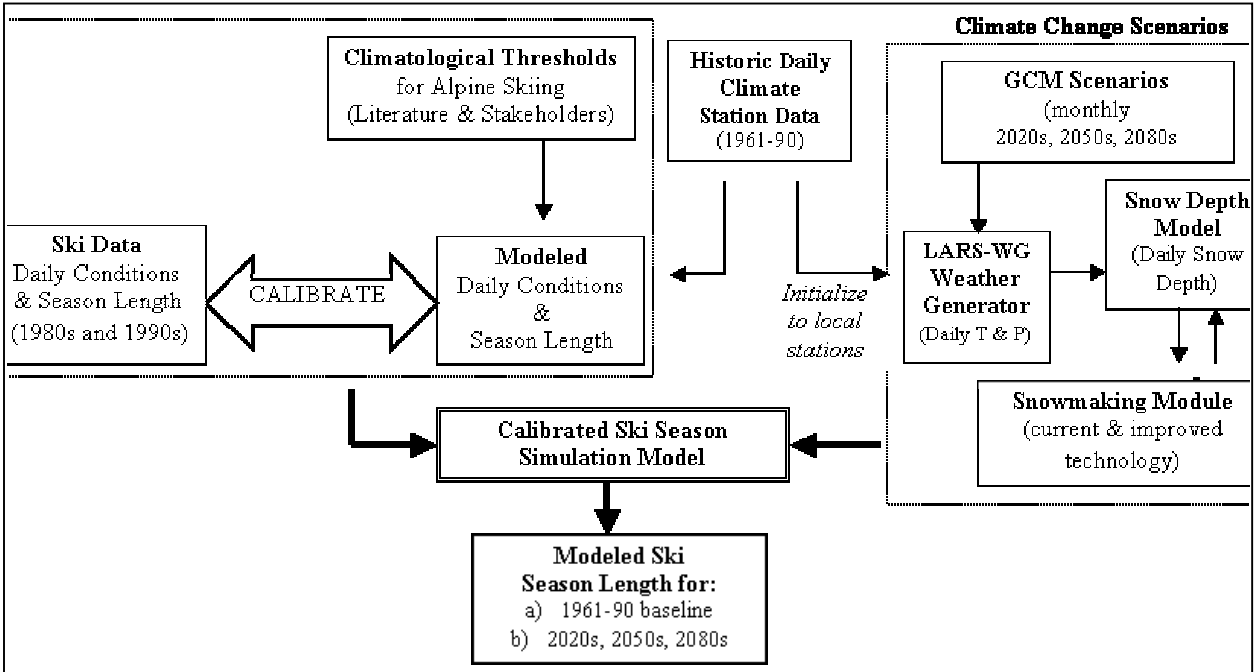
Figure 1 Methodological framework

can be made economically) and decision rules for the snowmaking module (e.g., when to start making snow to begin the ski season) were derived from communications with ski industry stakeholders in the study area. Anticipating technological improvements in snowmaking systems, the study also parameterized a snowmaking module with improved snowmaking capacities (able to produced snow economically at warmer temperatures and produce more snow per day).

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 climatic conditions occurred: snow depth < 30cm, maximum temperature >10^{0}C 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 observed data were available, the average season length was 124 and 123 days respectively (minimum seasons were 111 and 99 days and maximum seasons 140 and 152 days). Overall the ski season simulation model performed reasonably, missing the observed season length by more than seven days (~5% of an average season) in only five of 17 years.

3. CURRENT CLIMATE SENSITIVITY AND ADAPTATION

In order to reduce their vulnerability to climate variability, well-capitalized ski areas in the study region

have made multi-million dollar investments in snowmaking technology. All of the ski areas in the region now have 100% snowmaking coverage of skiable terrain.

The importance of snowmaking to Horseshoe Resort ski operations is clearly revealed in Figure 2, where the recorded natural snow depth at the Orillia climate station is compared with the reported snow depth (composed of natural snow fall plus snowmaking) at the Horseshoe Resort ski area. The difference between the natural snow depth and snow depth at the ski area represents snowmaking activity. In the years illustrated, the absence of snowmaking would have meant that the preferred 30cm snow base (solid line in Figure 2) for ski operations would have been achieved for only a very short time. The economic viability of the ski area during these low snowfall winters would have been questionable without snowmaking systems. The multi-million dollar investment in snowmaking extended the period with an operational 30cm snow base at the Horseshoe Resort ski area by 33% to 830% during the 1980s and 90s.

4. CLIMATE CHANGE IMPACT ASSESSMENT

As important as snowmaking was shown to be for the current viability of the ski industry in the study area (section three), the reduction in the number of days with a natural snow base of 30 cm suggests that by the 2020s the viability of the ski industry in the region would be in serious question without snowmaking. That was also the conclusion of earlier studies that examined
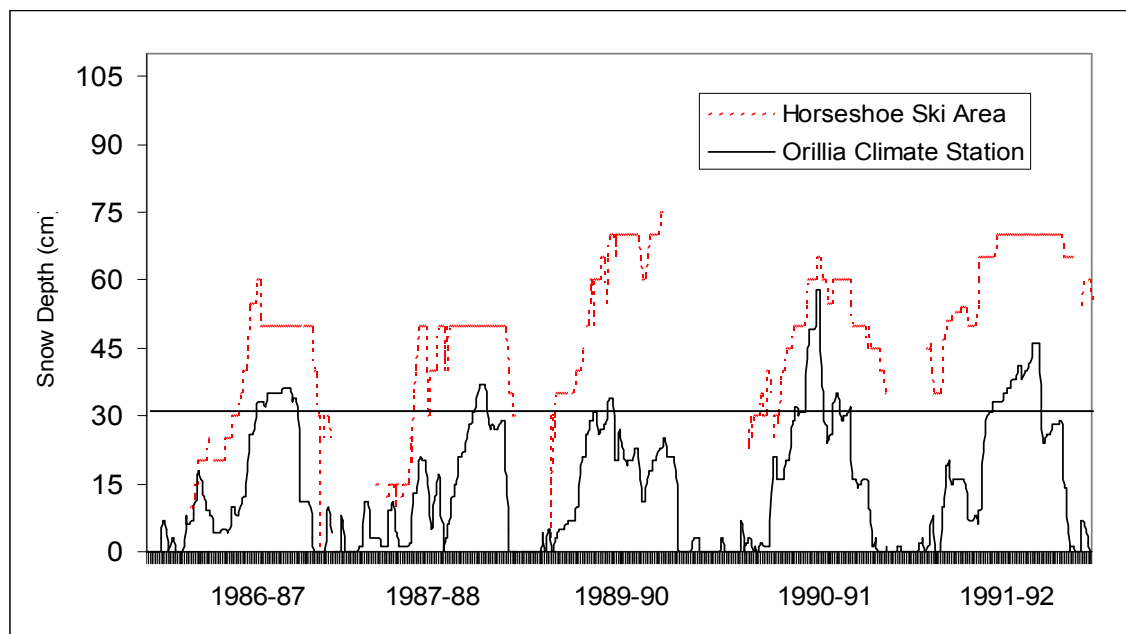
Figure 2 Comparative snow depth at Orillia climate station and Horseshoe ski area.

the potential impact of climate change on the ski industry in the region. McBoyle and Wall (1992) and Ordower (1995) projected 40-100% losses in the average ski season under two doubled carbon-dioxide (CO_2) equilibrium GCM scenarios. These studies were not able to account for the impact of the large investments in snowmaking systems that were taking place at the time.

The projected impact of climate change on the length of average ski season (Table 1) and snowmaking requirements at the Horseshoe Resort ski area differed substantially among the range of climate change scenarios selected for this analysis. 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, which are most relevant to business planning time frames. In the 2020s, the HadCM3-B2 scenario projected that with current snowmaking technology there would be no change to the average ski season (relative to the 1961-90 baseline) and little additional snowmaking required (136% of 1961-90 baseline). The HadCM3-B2 scenario projects the least DJF warming in the study area of all the GCMs considered, with precipitation increases that help offset additional snow melt from slightly warmer average temperatures. At the other end of the range of climate change projections for the 2020s, the warmer CGCM1-IS92a scenario projected a 16% reduction in the average ski season and a 144% increase in the amount of snowmaking required. With improved snowmaking technology, the ski season loss in the 2020s 'worst-case' CGCM1-IS92a scenario could be only 8% with an approximate

tripling (287% of 1961-90 baseline) in the amount of snow produced by snowmaking. Although the CCSR-IS92a and CSIRO-A2 scenarios projected similar DJF warming as CGCM1-IS92a, the substantial increase in DJF precipitation in these two scenarios (20% and 16% respectively), offset projected ski season losses and additional snowmaking requirements.

Regardless of the climate change scenario, average ski seasons continue to shorten as the magnitude of climate change increases in the latter decades of the 21st century (Table 3). The impact of the different climate change scenarios on the ski season and snowmaking requirements also becomes much more pronounced in the 2050s and 2080s.

5. CONCLUSION

The findings of this study were consistent with previous climate change impact assessments of the skiing industry, in that the scenarios utilized indicate an increasingly challenging business environment for the ski industry under climate change. In contrast however, the magnitude of the projected climate change impact was substantially diminished relative to previous studies because the research was able to incorporate snowmaking as a climate adaptation and examine a wider range of climate futures (SRES) that only recently became available through the IPCC and international climate modelling centres.

In this study, approximate doubled-atmospheric CO_2 equivalent scenarios (2050s) reduced the average ski season with current snowmaking capabilities between 7% (HadCM3-B2) and

Modeled 1961-90 Baseline = 123 days	Current Snowmaking Technology			Improved Snowmaking Technology		
	2020s	2050s	2080s	2020s	2050s	2080s
Climate Change Scenarios:						
CGCM1-IS92a	-16%	-32%	-48%	-8%	-21%	-35%
HadCM3-IS92a	-9%	-19%	-37%	-3%	-11%	-26%
CCSR-IS92a	-11%	-21%	-45%	-4%	-15%	-32%
CSIRO-A2	-9%	-19%	-50%	-3%	-11%	-39%
CGCM2-B2	-5%	-9%	-19%	0%	-3%	-11%
HadCM3-B2	0%	-7%	-11%	+5%	-1%	-4%

Table 1 Modeled ski season length (% change from 1961-90 baseline)

32% (CGCM1-IS92a) and 1% (HadCM3-B2) to 21% (CGCM1-IS92a) with improved snowmaking capabilities. These scenarios are more optimistic than earlier studies that estimated a 40% to 100% loss of the ski season in the study area under doubled-CO_2 conditions (McBoyle and Wall 1992, Ordower 1995). These more optimistic findings must be tempered with the uncertainty that the additional costs of snowmaking under warmer conditions may reach a threshold that becomes uneconomic.

The findings clearly demonstrate the importance of snowmaking as a climate adaptation and that the value of investments in snowmaking systems will only increase under climate change. In fact, Scott et al. (2002) found that the alpine skiing sector was less vulnerable to climate change in the study area than other winter recreation sectors (snowmobiling, nordic skiing, and ice fishing) because of the adaptive capacity provided by snowmaking.

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