CLIMATE CHANGE VULNERABILTY OF THE US NORTHEAST (USA) SKI INDUSTRY

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ABSTRACT Winter recreation is an important part of the cultural identity of the Northeast United States and is a multi-billion dollar contributor to the regional economy. This study examined the supply-side vulnerability of the alpine skiing industry under six climate change scenarios for the 21st century using the ski operations modeling approach developed by Scott et al. (2003; 2006; 2007) in Canada. Under all scenarios, natural snow became an increasingly scarce resource. The large investment in snowmaking over the past 25 years would substantially reduce the vulnerability of the ski industry until at least mid-century. Climate change posed a risk to only four of the 14 study areas in 2010-2039, where average ski seasons declined below 100 days and the probability of being open for the entire Christmas-New Year's holiday declined below 75 %. Conversely, by 2070-2099 only four study areas had not reached these same economic risk criteria. In order to minimize ski season losses, snowmaking requirements are projected to increase substantially, raising important uncertainties about water availability and cost. Climate change represents a notable risk to the ski industry in the Northeast under warmer scenarios, particularly more southerly ski areas and those at lower elevations. The potential economic ramifications for businesses and communities heavily invested in winter tourism and related real estate is sizeable and all communities with large ski tourism business should begin strategic planning to adapt to the anticipated impacts of climate change on the regional ski industry.

KEYWORDS: *Ski tourism, climate change, vulnerability, Northeast U.S.A., impacts*

INTRODUCTION

The winter-recreation sector has been identified as particularly vulnerable to climate change and is expected to see some of the first signs of change within the tourism-recreation sector (UNWTO, 2003, Scott et al., 2007). Changes will bring both negative impacts as well as potential opportunities for business operators as well as surrounding communities that rely on regional and local tourism infrastructure. The businesses and regions that are best able to adapt to potential changes will prosper and those which are unable to cope with rising temperatures, changing snowfall patterns, weather extremes and other related challenges will be most negatively effected. Ski tourism in particular is has been the focus of many climate vulnerability studies conducted around the world (Australia, Austria, France, Germany, Italy, Japan, Switzerland and the United States). Study results have consistently projected negative consequences for the ski industry mainly through altered amount and timing of natural snow fall causing a reduction in ski season lengths.

Climate change impacts on the winter-recreation sector could be significant considering snow-based recreation in the United States alone (encompassing alpine skiing Nordic skiing, snowboarding, and snowshoeing) was recently estimated to contribute $66 billion to the US economy and support approximately 556,000 jobs (Southwick Associates 2006). Just over 8% of the US population (15.5 million people) participate in these forms of snow-based recreation. The same study indicated that participation in snow-based recreation was higher (13%) in the U.S. Northeast (encompassing the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) and the economic contribution to the regional economy was $4.6 billion annually. Winter ski tourism in the U.S. Northeast alone has supported approximately thirteen million skiers and snowboarders annually for the past ten years (NSAA, 2005). There are over 100 ski areas in the region including small and large scale resorts located at both low and high elevations (ranging from 137 metres above sea level [masl] to 1353 masl).

As an economic sector that is highly influenced by climate, the U.S. Northeast ski industry may be profoundly affected by future global climate change. Since 1900, annual temperatures across the U.S. Northeast have increased an average of 0.08 °C (0.14 °F) per decade (Hayhoe et al., 2006). From 1970 to 2002, however, the region has been warming at a higher average rate of 0.28 °C (0.5 °F) per decade. This corresponds to an overall warming for the entire region during the last three decades of 0.97°C (1.75°F). The increase in average winter temperatures is even greater, rising an average 0.72°C (1.3°F) per decade since 1970 (Hayhoe et al., in press).

This paper examines the vulnerability of the U.S. Northeast ski industry at both a regional and market level scale. A total of 14 ski study areas (Connecticut, western and southeastern Maine, western and eastern Massachusetts, northeastern and southeastern New Hampshire, western, northeastern, and southeastern New York, western Pennsylvania, eastern Pennsylvania, and northern and southern Vermont) where selected to provide spatial coverage of the Northeast ski industry. From these study areas, 103 individual ski areas were examined allowing for investigation of both regional and local level vulnerabilities.

METHODS

To assess climate change vulnerability of the U.S. Northeast skiing industry gridded climate data (daily temperature and precipitation at 1/8° resolution) was used for both the baseline (1961-90) and future climate change scenarios. Six climate change scenarios were utilized including three different GCMs (HadCM3, PCM, GFLD) each run under two IPCC-SRES emission scenarios, representing a high emissions future (A1FI - 970 ppm) and a relatively lower emissions future (B1 - 550ppm). Changes in ski areas operations (season length and snowmaking requirements) were projected for three future time periods (2010-39, 2040-69, and 2070-99). These climate change scenarios are consistent with those used in the recent Northeast Climate Impact Assessment (Union of Concerned Scientists, 2006). The GCMs were specifically chosen for that assessment and also for this study because of their superior performance in reproducing historical climate in the region relative to other GCMs (Hayhoe et al., in press).

Ski operation data (i.e. season length and snowmaking requirements) are extracted using the ski operations modeling approach developed by Scott et al. (2003). The method has been applied in Canada and the United states (Scott et al. 2003, 2006, 2007, Dawson and Scott, in press). A physical snow model is at the core of the ski operations model, which uses daily temperature and precipitation inputs to model snow depth based on the calculation of three parameters: amount of precipitation that falls as snow and rain; snow accumulation; and snowmelt. A key limitation of previous climate change and ski tourism vulnerability studies was the complete absence of snowmaking causing over-estimations of the potential future impacts. The approach developed by Scott et al. (2003) considers snowmaking by including certain technical capacities (minimum temperature at which snow can be made economically, daily snowmaking capacity) and decision making rules within the snowmaking module (start/end dates, target snow pack depth to maintain). The snowmaking capabilities modeled represent those of an advanced snowmaking system and assumes 100 % coverage of skiable terrain. The assumption of 100 % coverage of advanced snowmaking capability is reasonable for most of the US Northeast ski areas in this study considering 81 of the 103 individual ski areas examined have snowmaking capabilities of between 75 and 100 % terrain coverage and only seven resorts have less than 50 % coverage capability. Because of this, and because it is possible for all resorts to develop a larger snowmaking capacity (i.e. adaptive capacity) all ski areas were modeled using the same snowmaking parameters.

The regional level assessment which examined 14 ski study areas evenly dispersed throughout the U.S. Northeast was modeled using a single hypothetical ski area with identical characteristics (e.g., size, snowmaking capacities and management practices). This approach isolates the importance of climate and projected climate change at each location, rather than assessing the relative technological (e.g., snowmaking) and business (e.g., four season operation) advantages of individual ski areas. This consistent methodology also facilitates comparisons of climate change impacts with competitors in the nearby ski regions of Québec and Ontario.

The market level assessment of 103 individual ski areas scattered throughout the ski study areas were modeled and tailored to elevation in order to account for the different temperatures and impacts that are expected to occur at different altitudes. Vertical adjustments were made to the temperature data extracted from the gridded climate data using a generic lapse rate of +0.65 °C per 100 m of elevation. The elevation of each ski area was represented by its mid-range elevation (summit – base/2).

RESULTS

Under all scenarios, natural snow became an increasingly scarce resource causing decreased ski season lengths and increased snowmaking requirements in both the regional and market level assessments.

Season Length

The climate change scenarios consistently projected shorter ski seasons for all 14 study areas throughout the U.S. Northeast. Under the lower emission (B1) scenario for 2010-2039, only three study areas were projected to lose less than 10 % of the ski season, while 10 study areas lost 10-17 % and only the Connecticut location lost more than 20 %. In 2040-2069, ski season losses were not substantially higher, with only the Connecticut location projected to lose greater than 25 % of its ski season. The level of climate change impact increased in the 2080s where half of the study areas were projected to lose 25 % or more of their ski season. The higher emission scenario (A1Fi) had a much greater impact on the length of ski seasons in the region, especially in 2040-2069 and beyond. In 2040-2069, eight of the study areas were projected to lose 25 % or more of their ski season. By 2070-2099 all 14 of the study areas had lost at least 25 % of the ski season and half of the study areas lost 45 % or more (Tab. 1).

Ski season lengths modelled at the 103 individual ski areas show decreases at all resorts. Modelled results from the ski areas located at higher elevations (i.e. many ski areas in New Hampshire and Vermont) show longer season lengths in all time periods than those resorts located at lower elevations (i.e. many ski areas in Connecticut, Mass, Maine, and New York).

In order for a ski area to remain profitable, it has been argued that ski season lengths need to be at least 100 days long. Under the higher emission scenario (A1Fi), the season length of all ski areas in Connecticut and Massachusetts drop to less than 100 days by the 2010-39 time period. In the 2040-69 time period 50 % of ski areas in Maine and New Hampshire and just 22% of ski areas in New York have season lengths of more than 100 days. By the 2070-99 time period 22 % of ski areas in New Hampshire and only 6 % of ski areas in New York have season lengths of greater than 100 days. Individual ski areas in Vermont are the least vulnerable with 94 % of ski areas maintaining ski season lengths of greater than 100 days into the 2070-99 time period. Modelled results from the B1 lower emission scenario project similar results with slightly fewer individual resorts experiencing season lengths of less than 100 days (Tab. 2).

Table 1: Modelled Change in Average Regional Ski Season Length (14 areas)

Study Areas	Baseline (1961-90) (days) [a]	Lower Emission Scenario (B1)			Higher Emission Scenario (A1Fi)		
		2010-2039 (% Δ) [b]	2040-2069 (% Δ) [b]	2070-2099 (% Δ) [b]	2010-2039 (% Δ) [c]	2040-2069 (% Δ) [c]	2070-2099 (% Δ) [c]
West New York	113	-15	-16	-29	-13	-27	-47
Northeast New York	147	-10	-12	-18	-10	-19	-34
North Vermont	147	-10	-12	-19	-9	-21	-37
South Vermont	158	-7	-11	-16	-9	-18	-33
Northeast New Hampshire	159	-8	-11	-16	-10	-19	-33
West Maine	172	-6	-8	-8	-6	-14	-25
Southeast New York	108	-14	-16	-27	-16	-28	-49
West Massachusetts	130	-13	-14	-24	-14	-24	-40
Southwest New Hampshire	129	-13	-15	-24	-13	-25	-42
Connecticut	100	-21	-25	-40	-23	-38	-59
East Massachusetts	126	-15	-17	-28	-15	-27	-45
Southeast Maine	122	-17	-17	-29	-15	-28	-48

[a] 30 year average of six baseline scenarios (HadCM3-A1Fi, HadCM3-B1, PCM1-A1Fi, PCM1-B1, GFDL-A1Fi, GFDL-B1)
[b] 30 year average of three scenarios (HadCM3-B1, PCM1-B1, GFDL-B1)
[c] 30 year average of three scenarios (HadCM3-A1Fi, PCM1-A1Fi, GFDL-A1Fi)
% Δ = percentage change

Snowmaking Requirements

In order to limit ski season losses to the levels described above, snowmaking requirements were projected to increase throughout the 14 study areas in the U.S. Northeast. Under the lower emission (B1) scenario for 2010-2039, snowmaking requirements would increase by at least 25 % at half of the study areas. In 2070-2099, climate change had distinctly different impacts on snowmaking requirements. Five of the study areas were projected to require at least 50 % more snowmaking and increases of 25 to 49 % were projected for an additional four locations. The remaining five study areas were projected to make the same amount or less machine-made snow in 2070-2099 than 2040-2069 due to the inability to make snow in unsuitably warm temperatures during the early and latter part of the current ski season.

Table 2: Individual Ski Areas with Ski Season Lengths Less than 100 days

	Total Ski Areas	2010-39		2040-69		2070-99	
		B1	**A1fi**	**B1**	**A1fi**	**B1**	**A1fi**
CT	5	0	0	0	0	0	0
Maine	14	8	8	8	7	7	7
Mass	12	1	0	0	0	0	0
NH	18	17	17	17	9	12	6
NY	36	13	13	13	8	9	2
VT	18	18	18	18	17	18	17
Northeast Region	103	57	56	56	41	46	30

The higher emission (A1Fi) scenario had a much greater impact on snowmaking requirements. In 2010-2039, nine of the study areas were projected to require at least 25 % more machine-made snow. In 2070-2099, three study areas were projected to require over a 100% increase in machine-made snow and four other locations require at 50 to 99 % more machine-made snow. Snowmaking in 2070-99 was projected to decline relative to 2040-69 in five locations (West Pennsylvania, East Pennsylvania, Southeast New York, West New York, and Connecticut) where warm temperature made it unfeasible during parts of the winter months (Tab. 3).

Table 3: Modelled Change in Average Annual Snowmaking Requirements

Study Areas	Baseline (1961-90) (cm) [a]	Lower Emission Scenario (B1)			Higher Emission Scenario (A1Fi)		
		2010-2039 (% Δ) [b]	2040-2069 (% Δ) [b]	2070-2099 (% Δ) [b]	2010-2039 (% Δ) [c]	2040-2069 (% Δ) [c]	2070-2099 (% Δ) [c]
[A] West New York	199	+18	+22	+22	+11	+20	+14
[B] Northeast New York	152	+33	+33	+55	+32	+53	+81
[C] North Vermont	119	+28	+33	+53	+33	+56	+89
[D] West Pennsylvania	225	+11	+16	+12	0	+12	+3
[E] South Vermont	101	+39	+39	+65	+42	+73	+108
[F] Northeast New Hampshire	79	+29	+37	+55	+35	+68	+120
[G] West Maine	57	+46	+58	+58	+43	+86	+155
[H] East Pennsylvania	186	+21	+25	+24	+20	+31	+27
[I] Southeast New York	188	+15	+15	+15	+13	+23	+18
[J] West Massachusetts	173	+21	+24	+37	+26	+36	+40
[K] Southwest New Hampshire	153	+27	+3	+38	+28	+53	+56
[L] Connecticut	217	+16	+23	+14	+13	+26	+5
[M] East Massachusetts	187	+25	+28	+36	+26	+38	+38
[N] Southeast Maine	144	+32	+36	+48	+26	+48	+73

[a] 30 year average of six baseline scenarios (HadCM3-A1Fi, HadCM3-B1, PCM1-A1Fi, PCM1-B1, GFDL-A1Fi, GFDL-B1)
[b] 30 year average of three scenarios (HadCM3-B1, PCM1-B1, GFDL-B1)
[c] 30 year average of three scenarios (HadCM3-A1Fi, PCM1-A1Fi, GFDL-A1Fi)
% Δ = percentage change

DISCUSSION

Shortened ski seasons and increased snowmaking requirements, which could potentially reduce revenues and increase operating costs, have important implications for the economic sustainability of ski businesses in the U.S. Northeast. Resorts that are most adaptable to changing climate generally include those at higher elevation where temperatures are lower, those with a diversified tourist product (i.e. all-season resorts), and those who are part of larger business conglomerates such as Interwest Corporation. Based on this analysis, it would appear that it is not the entire U.S. Northeast ski industry that is at risk to climate change but rather individual ski businesses and communities that rely on ski tourism. The probable consequence of climate change will be a continuation of the historic contraction and consolidation of the ski industry in the region. Although projected climate change would contribute to the demise of ski businesses in some parts of Northeast, it could advantage some of the ski operations that remain (e.g., northern Vermont and New Hampshire).

The large increase in snowmaking requirements under climate change scenarios also raises important questions about the sustainability of this critical adaptation strategy in certain locations. Communities and environmental organizations have expressed concern about the environmental impact of water withdrawals associated with snowmaking. Under the higher emission (A1Fi) scenario, where a 50-100 % increase in snowmaking was modeled at several locations, water conflicts may be heightened and access to water may be a critical constraint for future snowmaking. The economic costs of increased snowmaking (energy and water costs) were not factored into this assessment because the detailed economic information required is not publicly available. This remains a critical uncertainty for the future profitability of ski areas in the region and is a question that can only be adequately answered by ski area managers themselves.

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