Climate Change Vulnerability of the US Northeast Ski Sector

A multi-methods systems-based approach

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis.

This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

In its Fourth Assessment Report (AR4), the Intergovernmental Panel on Climate change estimated that global mean temperature will increase between 1.8 to 4.0°C by the end of the 21^{st} century. An increase in global temperature by even a few degrees could have significant environmental and economic impacts, and mean that economic sectors that are better able to adapt to a changing climate will prosper, and those that are not may decline, relocate or disappear.

Traditional resource sectors, which are highly reliant on environmental conditions, such as agriculture and forestry have been considering the implications of climate change for several decades. The tourism sector, which is also highly reliant on environmental factors, has only begun to consider the possible impacts of climate change over the past five to seven years. The integrated effects of a changing climate are anticipated to have far-reaching consequences for the rapidly growing global tourism economy and the communities that rely on the sector. In fact, the United Nations World Tourism Organization [UNWTO], United Nations Environment Program [UNEP] and World Meteorological Organization [WMO] identified climate change as the '*greatest challenge to the sustainability of the global tourism industry in the* 21^{st} *century*'.

The winter tourism sector has been repeatedly identified as vulnerable to climate change due mainly to the high susceptibility of mountain environments and the projected reduction in natural snow availability. The international ski industry has received the most detailed attention because of the sector's high cultural and economic importance in many regions. The multi-billion dollar ski sector is highly vulnerable to changes in both regional and local climate and as a result has been projected to experience decreased natural snow reliability resulting in decreased season length, increased snowmaking requirements, increased operating costs, and decreased revenues in association with decreased visitation.

The overarching goal of this dissertation is to examine climate change vulnerability (see glossary of terms, p. xi) (both- supply and demand-sides) for the entire US Northeast ski tourism sector in order to understand how the regional marketplace, as a whole, is likely to change in response to projected climate change. Previous research has been piecemeal in its approach (i.e. examining either supply or demand) and has largely neglected to examine climate change vulnerability of the ski sector from a systems-based perspective (i.e. examining both supply and demand for a single marketplace). Understanding how the US Northeast ski area marketplace may contract under climate change conditions including how ski area competitors may fair under future conditions, and how demand-side behavioural response is likely to occur, would allow ski area operators and managers to

develop and implement appropriate adaptation strategies that can help reduce the negative impacts of change while taking advantage of any opportunities.

The research revealed that there is likely to be a contraction of ski area supply, which favours those ski areas that are able to afford the increased cost of adapting to projected changes in climatic conditions. Ski areas that are situated at higher elevations or are located in the northern portion of the Northeast region, were found to be at an advantage due to lower temperatures and more precipitation falling as snow. Ski areas in Vermont, New Hampshire, Maine, and northeastern New York were projected to maintain longer season lengths, require less snowmaking and be more likely to be operational during the economically important Christmas-New Year holiday than ski areas in Connecticut or Massachusetts.

The extent to which skiers intend to change their skiing behaviour in response to the projected impacts on ski area supply were not significantly greater than the extent to which they already change their skiing habits when current conditions are poor. This suggests that the future response to climate change is likely to be similar to that which has been observed during marginal snow conditions of the past, and that demand for skiing opportunities is not likely to reduce proportionally to the expected reduction in supply. In which case, the ski areas that are able to remain operational under projected climate change, may be able to take advantage of a possible geographic market shift (i.e. greater demand/market share for ski areas that remain). If there is a net transfer of demand throughout the remaining marketplace, it would mean that some communities would need to prepare for development pressures (e.g. water use for snowmaking, real estate development, slope expansion, congestion) associated with the concentration of ski tourism in fewer areas, while others would need to prepare for economic diversification and investment in alternative industries (i.e. adapted snow-based industry or non-snow-based industry).

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Glossary of Significant Terms

Adaptation	Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation: *Anticipatory adaptation* – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation. *Autonomous adaptation* – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation. *Planned adaptation* – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state (IPCC 2007).
Climate Change	Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. See also climate variability (IPCC, 2007).
Climate Change Analogue	An analogue approach uses past climate data which is representative of future change along with past performance data allowing conclusions to be made about possible future impacts
Climate Model	A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity (i.e., for any one component or combination of components a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical, or biological processes are explicitly represented, or the level at which empirical parameterisations are involved. Coupled atmosphere/ ocean/sea-ice General Circulation Models (AOGCMs) provide a comprehensive representation of the climate system. More complex models include active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate predictions (IPCC, 2007).

Climate Variability	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC, 2007).
Greenhouse Gases	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. As well as CO2, N2O, and CH4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2007).
IPCC	The Intergovernmental Panel of Climate Change is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences (IPCC, 2009).
Projection	The potential evolution of a quality or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions – concerning, for example, future socio-economic and technological developments, that may or may not be realized – and are therefore subject to substantial uncertainty (IPCC, 2007).
Scenario	A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a 'narrative storyline' (IPCC, 2001).
Social-ecological systems	A social-ecological system consists of a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context (Glaser et al. 2008). Similar definitions have been proposed by the Resilience Alliance (Berkes et al. 2003). According to Dawson et al. (2009)

both supply-and demand-side influences need to be identified within a SES approach when examining climate change and the tourism sector. Therefore it is necessary to identify the potential influences that climate change may have on tourism operations and infrastructure (supply-side) while at the same time identifying the impact that those changes may have on tourist behaviour including destination choice and behavioural adaptation (demand-side).

Soft Systems Methodology — Peter Checkland's (1999) SSM is a qualitative technique that can be used for applying systems thinking to non-systemic situations. It is a way of dealing with problem situations in which there is a high social, political and human activity component. This distinguishes SMS from other methodologies which deal with HARD problems that are often more technology-orientated. SSM applies systems thinking to the real world of human organizations.

SRES — The storylines and associated population, *GDP* and *emissions scenarios* associated with the Special Report on Emissions Scenarios (SRES), and the resulting *climate change* and *sea-level rise scenarios*. Four families of *socio-economic scenario* (A1, A2, B1 and B2) represent different world futures in two distinct dimensions: a focus on economic versus environmental concerns, and global versus regional development patterns (IPCC, 2007).

Systems Theory — General systems theory was originally proposed by biologist Ludwig von Bertalanffy in 1928. Since Descartes, the "scientific method" had progressed under two related assumptions. A system could be broken down into its individual components so that each component could be analyzed as an independent entity, and the components could be added in a linear fashion to describe the totality of the system. Von Bertalanffy proposed that both assumptions were wrong. On the contrary, a system is characterized by the interactions of its components and the nonlinearity of those interactions. In 1951, von Bertalanffy extended systems theory to include biological systems and three years later, it was popularized by Lotfi Zadeh, an electrical engineer at Columbia University. (McNeill and Freiberger, p.22)

Vulnerability — Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity (IPCC, 2007).

Abbreviations and Acronyms

AR4	Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007)
CO_2	Carbon Dioxide
GCMs	General Circulation Models
GFDL	Geophysical Fluid Dynamics Laboratory
GHGs	Greenhouse Gases
HadCM2	Second Hadley Centre Coupled Ocean-Atmosphere GCM
IPCC	Intergovernmental Panel on Climate Change
km	Kilometres
masl	Metres above sea level
mi	Miles
NOAA	National Oceanic and Atmospheric Association
NSAA	National Ski Areas Association
PCM	Parallel Climate Model
SRES	Special Report on Emissions Scenarios
UNWTO	United National World Tourism Organization
UNEP	United Nations Environment Program
WMO	World Meteorological Organization
WTTC	World Travel and Tourism Council

Chapter 1: Introduction to the Manuscript

1.1 Problem Statement

In 2007 the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) (2007) concluded that climate change will impede the ability of many nations and communities to achieve sustainable development by the mid-21st century. Particular systems, sectors and regions have been identified as '*likely to be especially affected by climate change'*, including mountain regions, the tundra, Boreal forest, tropical rainforests, mangroves, salt marshes, coral reefs, agricultural low latitudes, low-lying coastal areas, the Arctic, Africa and small islands (IPCC, 2007). Factors contributing to the climate-related vulnerability (as defined by the IPCC – see glossary of terms, p. xi) mainly include increased mean temperature, changing precipitation patterns, sea level rise and increased frequency of extreme events such as drought or flooding (IPCC, 2007).

The IPCC (2007) estimated that global mean temperature increased by 0.74°C over the past 100 years (1896 to 2005) and that the warming trend experienced over the past 50 years has occurred at twice this rate (IPCC, 2007). Average global temperature is projected to increase a further 1.8 to 4.0°C by the end of the 21st century (IPCC, 2007). With warming of the climate system now considered '*unequivocal*' by climate scientists, conclusions have been drawn suggesting that some degree of climate change will be inevitable regardless of efforts made to reduce greenhouse gas emissions due to an atmospheric lag-effect (IPCC, 2007). Even with effective mitigation strategies, global average temperatures could increase by 0.5–2°C (Schellnhuber et al., 2006) and regional variations may be much greater (IPCC, 2007). An increase in global temperature by even a few degrees could have significant environmental and economic impacts (IPCC 2007), and mean that economic sectors that are better able to adapt to a changing climate will prosper, and those that are not may decline, relocate or disappear. This understanding has resulted in an urgent call for adaptation-focused research (Adger et al., 2005).

The integrated effects of climate change are anticipated to have far-reaching consequences for the rapidly growing global tourism economy and the communities that rely on the sector, given its high level of dependence on climate and the environment (UNWTO-UNEP-WMO, 2008). Climate change is not a distant problem for sustainable tourism as it is already influencing billion dollar investment decisions and travel patterns in some markets. For tourists, weather and climate are intrinsic components of the travel experience, and as such are central determinants of destination choice (Lohmann & Kaim, 1999; Hamilton & Lau, 2005; Gössling et al. 2006), which influence tourism spending (Agnew & Palutikof, 2006), and holiday satisfaction (Williams et al., 1997). Furthermore, all tourism destinations are affected by climate variability (see glossary of terms, p. xi) that can influence tourist demand, comfort and satisfaction as well as tourism operations (e.g., water supply, energy costs, insurance costs) and environmental resources crucial to tourism (e.g., glaciers, biodiversity, water levels, snow).

These implications led the United Nations World Tourism Organization [UNWTO], United Nations Environment Program [UNEP] and World Meteorological Organization [WMO] to identify climate change as the '*greatest challenge to the sustainability of the global tourism industry in the 21st century*'(UNWTO-UNEP-WMO, 2008). This statement was made after the release of both the 'Djerba' (UNWTO-UNEP, 2003) and 'Davos' Declarations (UNWTO-UNEP-WMO, 2008), issued after the first and second international conferences on climate change and tourism.

Due to its growing importance, academic literature on the interactions of climate change and tourism has grown rapidly, doubling between 1995-99 and 2000-04 (Scott et al., 2005). The recognition and commitment of certain governmental agencies, tourism leaders and academic researchers to understand the impacts of global climate change within the tourism sector is not surprising considering the enormous economic value of the industry globally. The World Travel and Tourism Council [WTTC] (2009) stated that in 2008, travel and tourism contributed 9.9% (US$ 5,890 billion) to Gross Domestic Product (GDP) and despite the recent economic downturn the sector's future contribution to GDP is estimated to continue to increase to approximately 10.5% GDP (US$10,855 billion) by the year 2018. Employment in the travel and tourism sector represented 8.4% of total global employment in 2008 (238,277,000 jobs – 1 in every 11.9 jobs) and has been estimated to increase to 9.2% of total global employment by 2018 (296,252,000 jobs – 1 in every 10.8 jobs) (WTTC, 2009).

In particular, the winter tourism sector has been repeatedly identified in academic literature and government reports as vulnerable to climate change due mainly to the high susceptibility of mountain environments (IPCC, 2007) and a predicted reduction in natural snow availability (see UNWTO-UNEP, 2003; Scott, 2005; US National Assessment Team, 2001; UNWTO-UNEP-WMO, 2008) (see Chapter Three, p. 45 for a summary of existing climate change and ski tourism literature). The international ski industry has received the most detailed attention due to the sector's high cultural and economic importance in many regions. Based on available studies, Scott and McBoyle (2007) estimated that revenues from the global ski industry reach US$9 billion annually. The National Ski Areas Association (NSAA) reported US revenues of almost US$3.3 billion in 2006 (NSAA, 2006).

Canada reported annual revenues of US$647 million (Statistics Canada, 2005), Western Europe and Japan reported revenues of over US$3 billion (Lazard, 2002) and Australia reported their ski industry's worth to be US$1.3 billion per year (National Institute of Economic and Industry Research, 2006).

The growing body of literature examining the impact climate change is expected to have on the multi-billion dollar international ski industry consistently projects the following impacts: decreasing snow reliability, shortening ski season lengths, increased snowmaking requirements, decreasing visitation, increased operational costs, the potential for decreasing profits and the eventual loss of ski area operations. The majority of these studies focus on supply-side impacts (i.e. ski area operations): Australia - Galloway 1988, König 1998, Hennessy et al. 2003, Bicknell & McManus, 2006; Austria - Breiling & Charamza, 1999, Steiger & Mayer 2008, Wolfsegger et al. 2008, Abegg et al., 2007; Canada - McBoyle & Wall, 1987, 1992, Lamothe & Périard, Consultants, 1988, Scott et al., 2003, 2006, 2007, Scott & McBoyle, 2007; France - Abegg et al., 2007; Germany - Abegg et al., 2007; Italy - Abegg et al., 2007 ; Sweden - Moen & Fredman, 2007; Switzerland - König & Abegg, 1997, Elsasser & Messerli, 2001, Elsasser & Bürki, 2002; United States - Lipski & McBoyle, 1991, Hayhoe et al., 2004, Casola et al., 2005, Dawson & Scott, 2007, Hayhoe et al., 2008, Scott et al., 2008, Dawson et al., 2009a). Far fewer studies focus on the effects of climate change on ski area demand (i.e. perception and behaviour): Australia – König, 1998; Austria – Unbehaun, et al., 2008; Canada – Shih et al., 2009; Japan - Fukushima et al., 2002; Switzerland – Behringer et al., 2000; USA – Dawson et al., 2009a, Hamilton et al., 2007), and no known studies examine both the supply and demand-side impacts simultaneously in order to examine the net effects of both.

Susceptibility of the ski tourism sector was clearly evident at the end of 2006 and beginning of 2007 with media headlines appeared almost every day from November 2006 through January 2007 reporting cancellations of World Cup ski races, late opening of ski areas and employee lay-offs (Table 1).

Table 1: Media headlines of climate change impacts on the ski sector

Date	Headline	Source
Nov 19, 2006	On melting pond; warm spell skating on the natural pond or a homemade flooded rink: what could be more exhilarating, healthy or fun? And, more recently, doomed?	Toronto Star
Nov 26, 2006	FIS officials worried about 'critical" lack of snow in Europe	Globe and Mail
Nov 26, 2006	Lack of snow at European ski hills creating havoc for World Cup	The Canadian Press
Nov 27, 2006	Lack of snow endangers World Cup season in Europe	Montreal Gazette
Nov 29, 2006	World Cup cross-country, snowboarding races changed	The Associated Press

Nov 30, 2006	World Cup races cancelled for lack of snow	Winnipeg Free Press
Nov 30, 2006	Alpine Skiing: Val-d'Isère races scrubbed	Ottawa Citizen
Nov 30, 2006	Warmth, no snow result in no skiing	Edmonton Journal
Nov 30, 2006	Snow shortage forces cancellation of cross-country ski races	The Canadian Press
Dec 1, 2006	Lack of snow causes ski jump Czech mate	Agence France Presse
Dec 2, 2006	Ski resorts left hot and bothered by lack of snow; Factbox	The Times
Dec 3, 2006	World Cup Skiing season is on thin ice	Pittsburgh Post-Gazette
Dec 5, 2006	Biathlon – Warm weather shoots down World Cup biathlon	Reuters
Dec 5, 2006	Nationwide lack of snow has slopes ski-free, fueling	El Pais – English Edition
Dec 5, 2006	Venice is sinking: climate change and tourism	CBC: The Current
Dec 8, 2006	Balmy temperatures, lack of snow threatens to cancel winter in Europe	The Canadian Press
Dec 9, 2006	Lack of snow hits home for Canadian athletes: Olympic skiers raise cash for Suzuki Foundation	Montreal Gazette
Dec 10, 2006	Lack of snow cancels ski races	Edmonton Journal
Dec 10, 2006	Skiing: Weather blights races	The Observer
Dec 13, 2006	OECD warns on Alpine ski future	BBC News
Dec 14, 2006	(S)no go for World Cup races: Lack of snow at European resorts results in cancellations	Vancouver Sun
Dec 18, 2006	Lack of snow of increasing concern in central Ontario tourism spots	The Canadian Press
Dec 21, 2006	Skiing goes downhill due to lack of snow	The Buffalo News (MCT)
Dec 22, 2006	Winter wondering; Lack of snow, cold halts skiers, snowmobilers, ice anglers	The Grand Rapids Press
Dec 26, 2006	Lack of snow means lack of snowmobilers	The Associated Press
Jan 3, 2007	Tourism operators in eastern Canada hoping for colder winter weather	CBC News
Jan 5, 2007	Ski hill feeling the blues from a lack of white	CBC News
Jan 5, 2007	Lack of snow, cold hurts ski business	Kennebec Journal
Jan 5, 2007	Lack of snow melts tourism in U.P.; Some winter events postponed while locals hope for cold	Grand Rapids Press
Jan 6, 2007	Blue Mountain lays off 1,300	Toronto Star
Jan 8, 2007	Lack of snow, mild weather forces Tour de Ski to cancel two races in Europe	Toronto Star
Jan 9, 2007	Ski jobs vanish as slopes, chalets sit empty	Toronto Star
Jan 13, 2007	David Suzuki on climate change and our environment	The Weather Channel

1.2 Methodological Approaches Used to Examine Climate Change Vulnerability in the Ski Tourism Sector

Methods that have been used to assess climate change vulnerability for the ski sector have traditionally included snow and ski season modeling, analogues and survey/interview-based techniques. Modeling-based techniques are the most regularly used approach and generally examine supply-side impacts including projections of future snow cover (Whetton et al., 1996; Breiling & Charmaza, 1999), snow reliability (defined as rising snow lines in mountainous regions) (König & Abegg, 1997; Abegg et al., 2007), changing season lengths (McBoyle et al., 1987, 1992; Lipski & McBoyle, 1991; Scott et al., 2003; 2006a; 2006b; 2008), operational probability during key holidays periods (i.e. Christmas/New Year and Mach break) (Scott et al., 2003; 2006a; 2006b; 2008), and snowmaking requirements (Hennessy et al., 2003; Scott et al., 2003; 2006a; 2006b; 2008).

Climate change analogue approaches (see glossary of terms, p. xi) have been employed, albeit much less often than modeling techniques (see Scott, 2005; Dawson et al., 2009a), and depending on the availability of required data sets can be useful in examining both supply-and demand-side vulnerability indicators. This technique involves comparing operational indicators (i.e. season length, snowmaking hours, visitation, operating profit etc.) during anomalously warm seasons of the recent past that are representative of average climate conditions expected in the future, with climatically average climate seasons of the past (i.e. baseline 1961-90). Conclusions can be drawn about what ski areas might expect to experience in the future when operating conditions occurring during unusually warm winter seasons become the norm under some future climate change scenarios.

Survey and interview-based techniques have traditionally been used to examine demand-side impacts for the ski tourism sector. Surveys are useful in investigating how participants have acted or intend to react to marginal snow conditions in the past, at present, or for projected future time periods (see König, 1997; Behringer et al., 2000; Unbehaun et al., 2008). Interviews have most often been used to examine skiers' perception of current and future climate change scenarios as well as adaptation strategies operators intend to employ to reduce impacts (Saarinen & Tervo, 2006; Keltie, 2007) (for definition of adaptation see glossary of terms, p. xi).

There are advantages and disadvantages to each of the methodological techniques used by climate change and ski tourism researchers (Table 2). One of the most important limitations of modeling studies is that many do not consider the wide-range of adaptation strategies that are already being utilized by individual ski areas to compensate for changes to natural snow conditions (see Elsasser & Bürki, 2002; Scott & McBoyle, 2007). As a result Scott (2005) suggested many studies likely overestimate the risk that climate change poses to ski operators, particularly in areas where the adoption of snowmaking is widespread, such as Eastern North America, Australia, Japan and parts of Western Europe. More recent studies including those conducted in North America (i.e. Scott et al. 2003, 2006; Dawson & Scott, 2007; Scott et al., 2008) and Australia (i.e. Hennessy et al., 2003) have incorporated snowmaking in assessments and as such are able to capture this important dimension in estimates of potential impacts. Secondly, modeling-based approaches are currently unable to project specific demand-side implications (i.e. how skiers change their behaviour/visitation patterns in direct response to poor conditions) or specific impacts on operating costs and profitability. In addition, due to the proprietary nature of individual ski area data, researchers in North America and Europe have noted difficulties obtaining data from the ski industry to assess changes in demand. In addition, modeling-based approaches do not incorporate individual operator business decisions (i.e. opening despite marginal conditions to accommodate overnight guests or opening a few runs while closing the majority of a ski area), which may cause models to overestimate impacts slightly. Where modeling-based studies are particularly useful is in examination of climate change impacts projected for distant time frames (i.e. as late as 2100), where no climate change analogue is available

In contrast to modeling-based approaches, analogues are currently only able to capture impacts expected for the 2010-39 and 2040-69 time periods due to the absence of winter seasons with average temperatures representative of high emissions climate change scenarios for distant time periods (i.e. 2070-99). However, they are able to evaluate a number of demand and economic-side indicators that are currently not possible through modeling approaches. An analogue approach examines actual or ‘real’ events, sometimes referred to as ‘natural experiments’, meaning the analysis is able to capture operator and participant (i.e. skier) decision making and adaptation strategies that were implemented during marginal snow events. However, the usefulness of this approach is highly dependent on the availability of operational data sets and on the quality, consistency and longevity of archived information. In addition, if appropriate data sets are available, information is generally aggregated due to the proprietary nature of individual business information, meaning that individual site level analysis of climate vulnerability is not possible.

Survey or interview-based approaches are useful in that they capture primary data from individuals or stakeholders at specific ski areas. Skier surveys have been very useful in helping to understand the extent to which individuals are likely to change their behaviour as a result of marginal snow conditions (see König, 1998; Behringer et al., 2000; Hamilton et al., 2007; Unbehaun, et al., 2008). However, there are three main limitations to the survey-based studies. First, the studies are not directly comparable due to inconsistent methodologies. Second, they ignore current behavioural patterns and only focus on future behaviour and therefore are unable to measure climate change-induced behavioural change. Third, they have yet to incorporate well-established behavioural psychology theory from the recreation and leisure fields, including useful theoretical constructs that could help elucidate not only that climate-induced behavioural adaptation is occurring, but also the reasons why, how and who is changing their skiing behaviour. Understanding these behavioural adaptations would allow ski area managers to plan adaptation strategies to reduce any negative tendencies and capitalize on any opportunities (see Bryan, 1977; Isa Ahola, 1986; Havitz & Dimanche,1990; Crawford et al., 1991; Mo, et al., 1992; Scott & Schafer, 2001).

Table 2: Advantages and disadvantages of approaches employed in climate change and ski tourism research literature

Approach	Advantages	Disadvantages
Modeling	• Able to examine a variety of future timeframes • Able to assess market-level impacts and regional impacts • Able to include snowmaking as an adaptation • Able to account for certain variables including improved snowmaking efficiency, elevation of ski area, snow depth required for operation etc. • Ski-sim model (Scott et al., 2003) can be calibrated to reproduces past climate and ski area conditions with reasonable accuracy	• Currently unable to examine demand-side implications due to proprietary nature of ski area information • Unable to capture 'human-element' (i.e. operator decision making) • Unable to examine economic-implications (proprietary information) • Requires availability of reliable climate data • Many do not incorporate snowmaking in empirical assessments • Non-standard methods and indicators (ski season length vs. snow reliability, elevation defined at top, mid and base of ski area)
Analogue	• Able to capture wide range of indicators including demand and economic-side variables • Reflects real operating conditions including operator and skier decision making • Relatively easy and quick to complete • Inexpensive	• Generally limited to short time futures • Limited to available data sets • Individual ski area assessments not currently possible (proprietary business information) • Based on single season anomaly but future projects change in average conditions (i.e. consecutive years of marginal conditions)
Tourist/Operator Survey/Interview	• Able to gather information on individual ski areas • Incorporates human element including decision making influences • Able to develop instruments to examine study specific objectives • Can evaluate behavioural change, perceptions and opinions	• Unable to account for the differences between stated and revealed behaviour • Unable to capture latent demand market • Findings are only as reliable as the survey instrument/instrument design • Data collection time and costs • Most ignore current behaviour patterns and focus on future, therefore can not measure change • Non-standard survey instruments meaning results are not directly comparable

1.3 Conceptualizing the Study Using a Systems-Based Framework

Due to the wide variety of approaches and methodologies that have been utilized throughout the climate change and ski tourism literature, most studies are not comparable, making it challenging to understand the differences in vulnerability between local, regional, national and international ski area marketplaces. In addition, no known studies simultaneously examine the impact of climate change on both the supply-side and demand-side of a ski tourism marketplace in order to explore the net effects of change (Shaw & Loomis, 2008). This makes Scott et al.'s (2008) very important suggestion to determine where the ski industry might contract to, and outline which communities may need to prepare for what type of future change a very difficult task.

Because the tourism industry only began to recognize its vulnerability to climate change over the past five to seven years (e.g. the 'Djerba' and 'Davos' Declarations by the UNWTO-UNEP, 2003; UNWTO-UNEP-WMO, 2008), knowledge of the ability of current climate adaptations to cope with future climate change remains very limited (Gössling, 2007; UNWTO-UNEP-WMO, 2008). The implications of climate change are likely to vary substantially by market segment and geographic region, and will partially depend on the impacts experienced by competitors. For example, marketplace competition is likely to decline as individual operators become unable to afford the cost of adapting to future climatic conditions (i.e. by investing in higher efficiency snowmaking technology, raising slopes to higher elevations etc.). If demand remains stable or dilutes proportionally less than supply, there would be a net transfer of demand throughout the remaining marketplace meaning that some communities may need to prepare for development pressures (e.g. water use for snowmaking, real estate development, slope expansion, congestion) associated with the concentration of ski tourism in fewer areas, while others will need to prepare for economic diversification and investment in alternative industries (i.e. adapted snow-based industry or non-snow-based industry). However, the climate change and ski tourism literature remains piecemeal including investigations of either supply or demand-side impacts (see Shaw & Loomis, 2008) for a variety of different geographical regions (see Shih et al., 2009) with limited attention given to how the system is likely to be impacted as a whole.

A systems approach (see glossary of terms, p. xi), which considers a wide variety of multifaceted and dynamically related factors, could provide a more comprehensive framework for guiding decision making, as well as further research[1]. Complex problems in the tourism literature have traditionally been examined linearly and in piecemeal sections instead of as a (whole) system. This is reflected directly in the climate change and tourism literature in which many studies examine climate as a single influencing factor on a static social system (*i.e.* “business as usual”) (*e.g.* Fukushima et al., 2002) often ignoring behavioural adaptation (*e.g.* Whetton et al., 1996), when in reality social influences (changing cost of fuel, changing demographics) are numerous and dynamic. The need to better integrate socio-economic scenarios in climate change impacts and adaptations research is well-documented (Berkhout et al.,2001; Lorenzoni et al., 2000; Shakley & Deanwood, 2003). Even the IPCC (2007) recommends integrated approaches to manage future climate change and related socio-economic impacts within all major sectors.

Tourism researchers are beginning to identify the usefulness of examining the tourism industry as a ‘system’ (see Leiper, 1990; Hall & Butler, 1995; Laws et al., 1998; McKercher, 1999; Russell & Falkner, 1999; Papatheodorou, 2004; Farrell & Twining-Ward, 2004; Walker et al., 2005; Patterson, et al., 2006; Dawson et al., 2007), and some even identify the perspective as specifically useful for investigating the influence of climate change on tourism (i.e. Patterson et al., 2006; Dawson et al., 2007; Dawson at al., 2009a).

The origin of systems thinking can be credited to biologist Ludwig von Bertalanffy and others in the 1930’s and 1940’s, but it was most developed from the 1950s onward. By the late twentieth century many disciplines, including resource and environmental management (*e.g.* Grzybowski & Slocombe, 1988; Berkes & Jolly, 2001; Berkes, et al., 2003), had embraced systems thinking, developing both hard systems approaches (more quantitative) and soft systems approaches (more participatory – see glossary of terms, p. xi) (also see Jackson, 2003 for a survey; or Checkland, 1999). More recently systems thinking has been greatly influenced by ideas derived mainly from physics and chemistry, and commonly discussed in terms of chaos, complexity and self-organization theories.

Climate change fosters environmental, social and economic change and uncertainty, making it hard to plan for sustainable tourism outcomes. The interconnected and interacting impacts on both environmental and social systems make management of tourism both difficult and complex. Systems approaches can provide tools for analysis, and for thinking about how to foster resilience, adaptation and sustainability (*e.g.* Folke, et al., 2003). In particular, a ‘social-ecological systems’ (SES) (see glossary of terms, p. xi) approach aims to establish greater understanding of complex eco-social

[1] The systems framework section is a synthesis of some conceptual ideas published by the author and colleagues in Dawson et al. (2007) and Dawson et al. (2009).

problems, such as those seen within the tourism industry, by analyzing the behaviour of a system as a whole and also in its individual parts rather than simply examining separate components in isolation of each other. According to Dawson et al. (2009b) both supply-and demand-side influences need to be identified within this type of SES approach when examining climate change and the tourism sector. For example, it is necessary to identify the potential influences that climate change may have on tourism operations and infrastructure (supply-side) while at the same time identifying the impact that those changes may have on tourist behaviour including destination choice and behavioural adaptation (demand-side). Scott and McBoyle (2007) further outline the importance of considering both the supply and demand sides when planning and implementing climate change adaptation strategies (Figure 1).

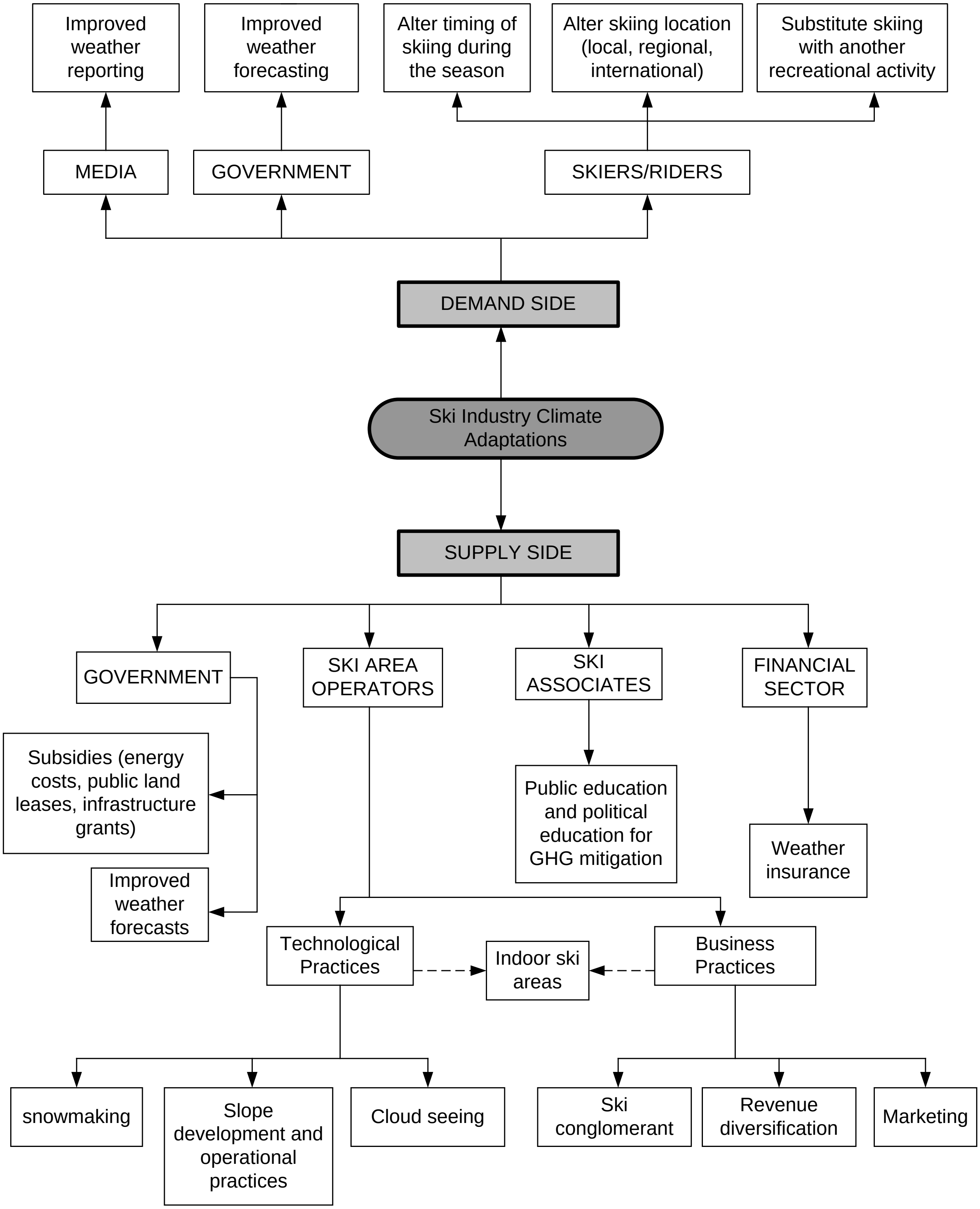


Figure 1: Ski Industry Adaptations (Scott & McBoyle, 2007)

1.4 Research Goal and Objectives

The multi-faceted impacts of climate change, which occur at multiple scales warrant a theoretical approach which is able to examine complex and integrated issues. This study employs a systems-based approach to examine climate change vulnerability of the US Northeast ski sector by including an investigation of current and future impacts for both supply (i.e. operations) and demand (i.e. participation and behaviour). The US Northeast ski region, as defined by the National Ski Areas Association [NSAA], includes approximately 103 ski areas scattered throughout the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont. The mid-range elevation of ski areas in the region varies from 137 metres above sea level (masl) to 1353 masl (NSAA, 2008; USGA, 2008). This study region was chosen for two main reasons. Firstly, climate data at the appropriate scale and resolution was readily available, and secondly, the sector has been identified as culturally and economically significant. For example, participation in snow-based activities (not including snowmobiling) in the US Northeast was estimated to contribute $4.6 billion to the region's economy annually (Southwick Associates, 2006) and the region boasts the highest skier/snowboarder participation rate in the country (National Sporting Goods Association, 2005).

In order to determine overall vulnerability of the US Northeast ski sector, three main objectives were established as well as several associated research aims:

Objective 1: To use a climate change analogue to examine the influence that anomalously warm temperatures and marginal snow conditions of the past, have had on regional ski area operations (supply-side) and skier demand;

Aim 1**:** examine the impact of unusually warm seasons of the past on season length, snowmaking hours, snowmaking power utilized, skier visits and operating profit;
Aim 2: consider the effect of ski area elevation as a factor in vulnerability;

Objective 2: To use modeling-based techniques to project future climate change impacts on ski area operations (supply-side);

Aim 3: project the impact of future climate change for, ski area season length, snowmaking requirements and probability of being operational during the economically important Christmas-New Year holiday period;
Aim4: consider the influence of ski area elevation for projected vulnerability;
Aim 5: examine contraction of the ski area marketplace based on economic sustainability;

Objective 3: To use a skier survey to understand behavioural responses to historic marginal conditions and expected supply-side impacts (demand-side);

Aim 6: examine how skiers have responded in the past, and intend to respond in the future, to marginal snow conditions;
Aim 7: understand the role of substitution and specialization within specific behavioural responses;
Aim 8: examine the extent to which commitment (i.e. involvement in the activity of skiing), and loyalty (i.e. to ski areas), influences climate-induced behaviour change.

This is the first known study to examine climate change vulnerability of both supply and demand for an entire regional ski marketplace. Understanding the differential impacts (both supply and demand) expected throughout the US Northeast region allows conclusions to be made about how the industry might contract under future climate change scenarios, what type and intensity of resulting demand-side market shift may occur, and outline what type of adaptation strategies are appropriate for ski area operators and nearby communities that are expected. This understanding could allow ski area operators to develop and implement appropriate planning and policy which is currently very difficult considering the lack of comprehensive understanding of future climatic impacts.

As acknowledged earlier, a full systems study examining climate change vulnerability for the US Northeast ski sector should include analysis of supply-and demand-side impacts as well as the outside influences of change (i.e. demographics, economics, fuel costs and social trends). Examining the outside influences of change in addition to the objectives set forth in this dissertation was beyond the scope of this study. According to Dawson et al. (2007) a full systems approach to examining climate change vulnerability in the tourism sector "*is a large undertaking; one which requires a team approach including knowledge of various interrelated subjects*" (p. 80). Figure 2 outlines the framework for a full systems study examining climate change vulnerability of the US Northeast ski sector. Highlighted in darker grey are the portions of the approach that have been conducted within this study (steps 1-3) and outlined in lighter grey are the steps that will need to be conducted within a future study (steps 4-6) (see section 6.4 for additional details on the proposed future research agenda).

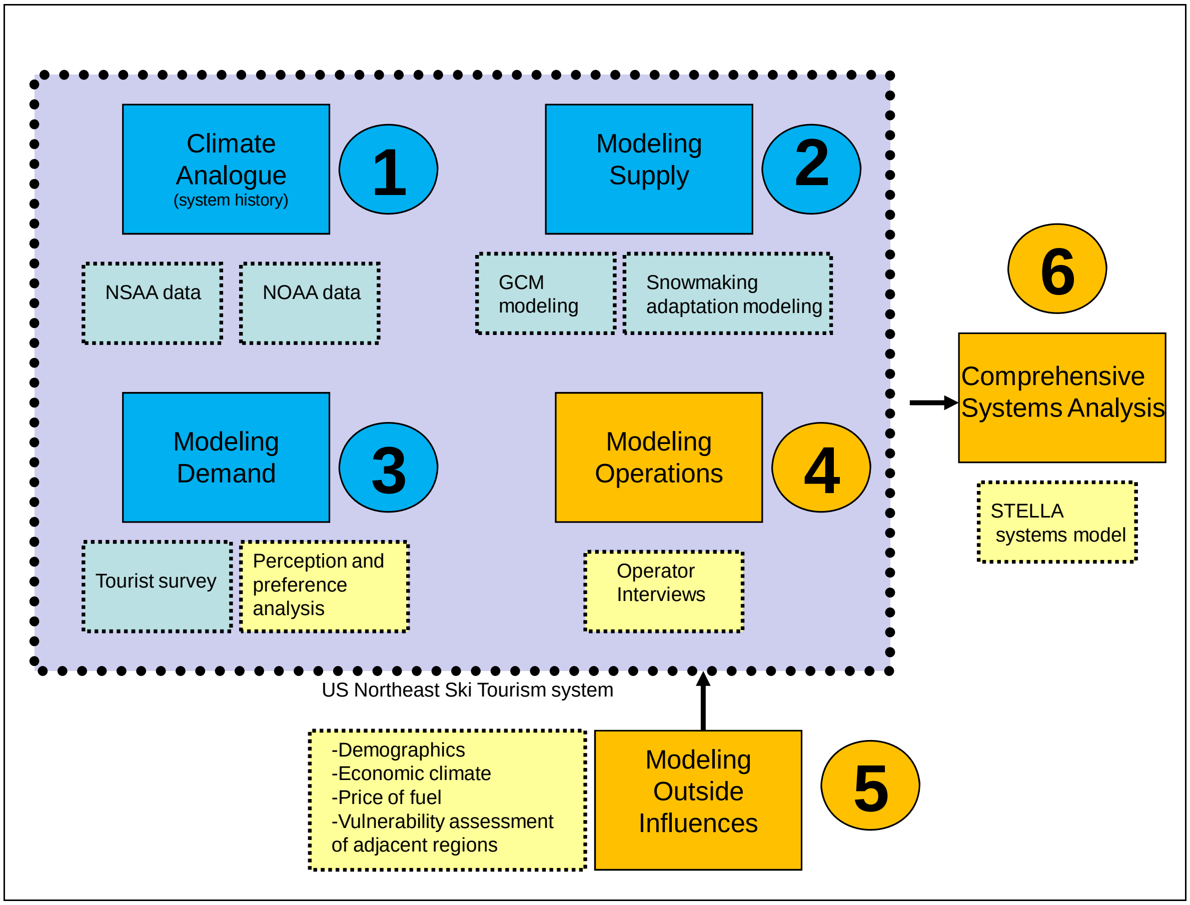


Figure 1: Systems-based methodology for examining the climate change vulnerability of the US Northeast ski sector

1.5 Outline of the Dissertation

This dissertation uses the manuscript format and consists of four papers that have been, or will shortly be submitted for peer-review publication in academic journals. Collectively these papers aim to meet the overarching goal and objectives set forth in this study.

The introductory chapter outlines the problem statement, conceptual framework, goal and objectives of the study. The second chapter focuses on achieving objective one through a paper titled, '*Analogue analysis of climate change vulnerability for ski tourism in the US Northeast'*, which has been accepted for publication (February, 2009) in '*Climate Research'*. In this chapter the results of a climate change analogue assessment are presented, which was used to examine the influence that anomalous high temperatures and marginal snow conditions of the past (representative of normal future conditions), have had on US Northeast regional ski area. Both supply-and demand-side indicators are examined as well as some economic variables for ski areas. Chapter three focuses on objective two of this dissertation and is a paper titled, '*Modeling climate change impacts on ski season and snowmaking in the US Northeast'*, which is planned for submission to the journal '*Tourism Management'*. This paper presents projections of future climate change impacts for 103 operating ski areas throughout the US Northeast (i.e. season length, snowmaking requirements and probability of being operational during key holiday periods) and discusses the anticipated future contraction of the regional marketplace as some ski areas become unable to afford the increased costs of adaptation. Chapters four and five focus on the third objective of this dissertation. Chapter four presents a paper planned for submissions to '*Journal of Travel Research*', titled '*Climate change and behavioural adaptation of skiers in the US Northeast*', which examines the influence that modeled climate change projections have on skier visitation patterns including behavioural substitution (spatial, temporal, activity). The Fifth chapter includes a paper titled '*Examining the influence of involvement and loyalty on climate-induced substitution behaviour of downhill skiers in the US Northeast'*, which will be submitted to '*Journal of Travel and Tourism Marketing*'. This paper incorporates theoretical constructs from the recreation/leisure behaviour literature to help examine not only who is more or less likely to change their participation behaviour because of climate change but also why. The final chapter (Chapter 6) summarizes the research findings, outlining both the impacts that are projected for the supply-side and demand-sides of the US Northeast ski sector. Significant conclusions are discussed and an agenda is set out for future research.

Chapter 2: Climate Change Analogue Analysis of Ski Tourism in the US Northeast

Detrimental impacts have been projected in numerous climate change studies examining the international ski tourism industry. Modeling-based studies have projected shortened ski seasons and increased snowmaking requirements under warmer temperatures. This study uses a climate change analogue approach to examine how a wider range of ski area performance indicators were affected by anomalously warm winters in the Northeast region of the US. The record warm winter of 2001-02 is representative of projected future average winter climate conditions in the US Northeast region under a high greenhouse gas emission scenario (ccsm A1B) for the 2040-69 period and was used as one climate change analogue for this analysis. The 1998-99 ski season was also used as a climate change analogue as it represents the last of three consecutive warm winters (1997-99) that are representative of a mid-range emissions scenario projected for the 2040-69 period (ccsm B1). Ski area performance indicators for the 2001-02 and 1998-99 analogue years were compared to the climatic normal (for 1961-90) years of 2000-01 and 2004-05. The indicators examined include: ski season length, snowmaking (hours of operation and % fuel utilized as a proxy for fuel costs), total skier visits and operating profit (% of total gross fixed assets). The revealed impact of ski season length during the climate change analogue years is compared with modeled impacts for the region. The differential vulnerability of small, medium, large and extra-large ski areas was also examined with the greatest economic impacts found among the small and extra-large sized ski areas.

Keywords: ski tourism, analogue, climate change, US Northeast

2.1 Introduction

Weather and climate significantly influence the tourism and recreation industry (Perry 1997), particularly in sectors which rely heavily on natural resources for participation. The multi-billion dollar international ski industry has been identified in multiple studies and government assessments as highly vulnerable to changes in regional and local climate because of the strong reliance on natural snow availability or cold temperatures to make snow (Australia – Galloway, 1988, Hennessy et al., 2003, Bicknell & McManus, 2006; Austria - Breiling & Charamza, 1999, Wolfsegger et al., in 2008, Abegg et al., 2007; Canada - McBoyle & Wall, 1987, 1992, Lamothe & Périard Consultants, 1988, Scott et al., 2003, 2006, 2007, Scott & McBoyle, 2007; France - Abegg et al., 2007; Germany - Abegg et al., 2007; Italy - Abegg et al., 2007; Japan - Fukushima et al., 2002 ;Sweden - Moen & Fredman, 2007; Switzerland - König & Abegg, 1997, Elsasser & Messerli, 2001, Elsasser & Bürki, 2002; United States - Lipski & McBoyle, 1991, Hayhoe et al., 2004, Casola et al., 2005, Dawson & Scott, 2007, Scott et al., 2008).

Most of the above climate change impact studies conducted on the international ski industry utilize a variety of modeling-based methodologies to estimate future changes to snow conditions and supply-side indicators (e.g. ski season length and snow reliable ski areas). The majority of these studies neglect to consider the wide-range of adaptation strategies that can be implemented by individual ski areas in order to compensate for changes to natural snow conditions (see Elsasser & Bürki, 2002; Scott & McBoyle, 2007). The exceptions are several studies conducted in North America (i.e. Scott et al., 2003; 2006; Dawson & Scott, 2007; Scott et al., 2008) and Australia (Hennessy et al., 2003) which incorporate the widely used adaptation of snowmaking. As a result Scott (2005) suggested many studies likely over-estimate the risk that climate change scenarios pose to ski operators.

The focus of recent climate change and ski tourism research in North America has been on modeling potential decreases in ski season length, while considering the increasing snowmaking requirements necessary to compensate for the projected reductions in natural snow availability (see Scott et al., 2003, 2006, 2007; Dawson & Scott, 2007; Scott et al., 2008). When snowmaking was accounted for, Scott et al. (2003, 2006, 2007) found the vulnerability of ski areas in the Canadian Provinces of Ontario and Quebec was reduced substantially compared to that reported in earlier studies for the region that did not include snowmaking (McBoyle and Wall, 1987, 1992; Lamothe & Périard Consultant, 1988).

A major limitation of the modeling-based approach is an understanding of how changes to season length and snowmaking requirements will affect skier demand patterns as well as operating costs and profitability of ski areas. This knowledge gap is partially related to the proprietary nature of information from ski area businesses. It is generally hypothesized that ski area expenditures would rise due to increased snowmaking requirements which will augment labour and power/fuel expenditures as well as water requirements. Increases in operating costs will be greater for ski areas located at lower elevations where more snowmaking will be required to compensate for warmer temperatures in comparison to ski areas located at cooler higher altitudes (Dawson & Scott, 2007).

These research limitations can be overcome using a climate change analogue approach (see glossary of terms, p. xi) to assess the potential impacts on supply- and demand-side indicators that are available from the ski industry. As Scott (2005) noted, an analogue approach has been under-utilized in climate change and tourism studies and has the potential to offer new insights into the future impacts and effectiveness of adaptations. For example, Scott (2005) found the decline in skier demand in a 2050s analogue winter in Eastern North America to be only 10-15%, which is far less than survey studies of hypothetical behaviour change have projected (e.g. König, 1998; Behringer et al., 2000). The analogue approach is a useful method for identifying the possible future impacts of global climate change, as it assesses impacts during real events and includes adaptation strategies and business decisions made during an anomalous ‘short term’ event, which may in the future become the norm. A key advantage of the climate change analogue approach is that it captures the full range of supply- and demand-side adaptations (i.e. by ski operators, marketers and skiers).

Similar to modeling approaches, a limitation of an analogue methodology is the inability to predict future influencing conditions, including technological advances (i.e. advanced snowmaking), changing behavioural responses (i.e. substitution behaviour), changing demographics and increasing price of energy for transportation and ski area operations. In addition, analogues are only available for short to medium term climate change scenarios since few analogue situations have occurred that are representative of long-range modeled climate futures under high GHG emissions scenarios (e.g. 2070-99 A1fi).

The use of analogues in the climate change and tourism literature has thus far been extremely limited (see Giles & Perry, 1998; Scott, 2005). As mentioned, Scott (2005) examined skier demand compared with skier responses in eastern Canada and United States during analogously warm seasons. More generally, Giles & Perry (1998) found the dry and warm UK summer of 1995 resulted in decreased outbound tourism compared to average climatic years.

The analogue approach requires that data on impact indicators be available for both climate change analogue periods and climatically normal periods (baselines). The National Ski Areas Association (NSAA) has conducted an annual review of the state of the US ski industry since 1973 through a detailed survey of its membership (NSAA, 2008). The data submitted by individual ski operators is aggregated to produce regional results (i.e. for Northeast, Southeast, Midwest, Rocky Mountain and Pacific West) in order to protect the proprietary nature of sensitive business information. This regional ski industry data was utilized in this analogue study. Although NSAA data is available for all five ski regions in the US, to explore the value of the analogue approach, this study focused only on the Northeast region, where previous modeling studies revealed notable vulnerabilities and were available for comparison.

The US Northeast ski region (Figure 3), which includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont, consists of over 100 ski areas ranging from 137 metres above sea level (masl) to 1353 masl (NSAA 2008, USGA 2008). Although, mountains in this region represent some of the highest ski area elevation in Eastern North America many ski resorts in the area have base levels lower than 450 masl. These lower resorts are expected to be particularly vulnerable under warming trends because of a reduced season length and the aforementioned increase in costs due to increased snowmaking (Scott et al., 2008).

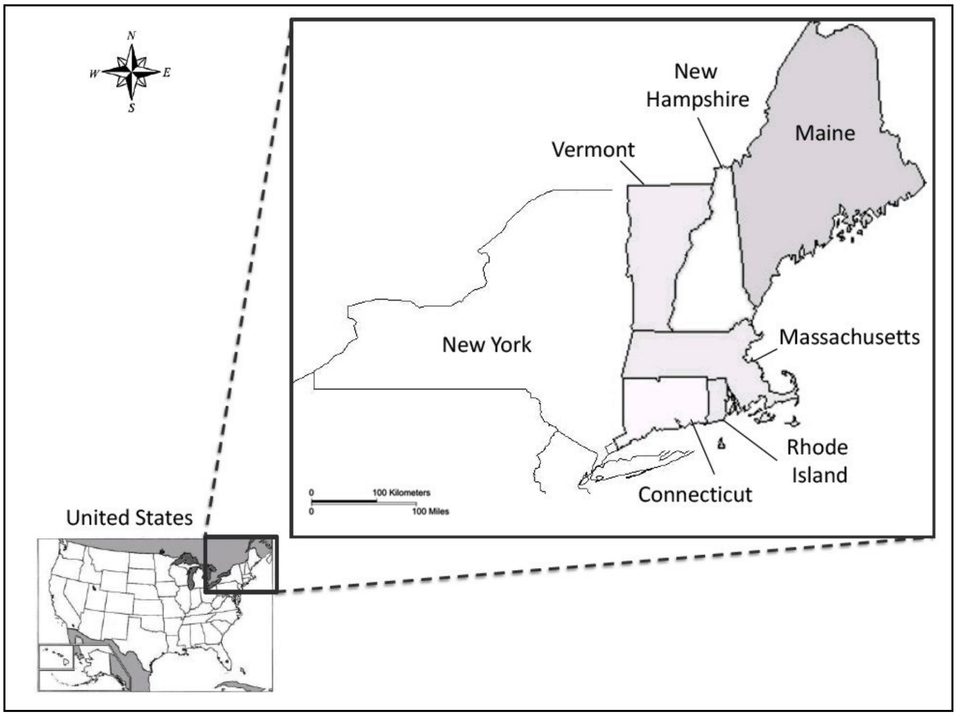


Figure 2: US Northeast region as defined by the National Ski Areas Association

Skiing in the US Northeast is not only culturally important, it is also economically significant. Participation in snow-based activities in the region is estimated to contribute $4.6 billion to the US Northeast economy annually (Southwick Associates, 2006). Individuals ski an average of 10 times per season in the US Northeast, which is the highest participation rate in the country (National Sporting Goods Association, 2005). Of the ski regions in the US, the Northeast consistently records the second highest total visitation rate (average ~13.5 million skiers), second only to the Rocky Mountain region (average ~19 million) (NSAA, 2001, 2004, 2005)

2.2 Methods

In this study, a climate change analogue approach is used to examine how a wide range of ski area performance indicators were affected by anomalously warm winters in the US Northeast region. Although an analogue assessment of individual ski areas would be a fruitful exercise, this study examines climate change impacts at a regional scale because individual ski area information is not available due to the proprietary nature of specific business information. Two types of regionally aggregated annual NSAA reports, the '*Kottke End of Season Survey'* and the '*Economic Analysis of*

United States Ski Areas', are publically available and provide operational performance information on US Northeast ski areas for the past two decades. Performance indicators were compared between climatically normal (average for the 1961-90 period) versus anomalously warm winters to determine the impacts of warmer temperatures, which are considered analogues for normal winter conditions under future climate change scenarios.

Historic temperature and precipitation data for the US Northeast was derived from the National Oceanic Atmospheric Association, National Climate Data Center (NOAA, 2008). Temperature data was primarily used to choose the analogue seasons, however precipitation was also considered. In 2001-02 the US Northeast region experienced a record warm winter season (+4.4°C/ 7.5°F above 1961-90 normal) that is representative of projected future average winter temperatures under a high greenhouse gas emission scenario (ccsmA1B) for the 2040-69 time period (for detailed regional climate change projections see Hayhoe et al. 2008, Frumhoff et al. 2008, and Pacific Climate Impacts Consortium, 2008). Future winter precipitation for the US Northeast is projected to increase by 30% under a high emissions scenario (A1fi) by the end of the century (Hayhoe et al., 2008). During the 2001-02 season precipitation decreased 20% below the 1961-90 average. Because of this, the impacts experienced during this analogue season do not exactly portend those of climate change scenarios and in this study may over-estimate impacts for ski areas at higher elevations. For example, it is important to consider both the benefits and drawbacks of increased precipitation for ski areas in this region under warmer temperature regimes. Increased precipitation could still fall as snow at higher elevations under mid-century scenarios but as rain at lower areas, which could also exacerbate the impacts at lower elevated ski areas.

It is possible that a ski area may be able to rebound financially after experiencing one poor snow season amongst a series of average or above average seasons. However, it is much more difficult to financially recover after experiencing two and three poor seasons consecutively (Scott & McBoyle, 2007). To account for this, a second analogue period, the 1998-99 ski season, was chosen as it represents the last of three consecutively warm winters (1996-97 to 1998-99) that are representative of a mid-range emission scenario (ccsmB1) for winter conditions during the 2040-69 time period (+ 2.7°C/4°F above 1961-90 period). During the 1998-99 season precipitation was 7.5% above the 1961-90 average. Precipitation projection for the 2040-69 time period under a mid-range emissions projection (B1) is +20% therefore the mid-range emissions analogue in this study provides a reasonable analogue for both future temperature and precipitation.

The climatic analogue seasons (2001-02 and 1998-99) chosen for this study are representative of some of the most marginal natural snow seasons experienced within the US Northeast over the past

112 years. The 2001-02 climatic analogue is representative of the warmest winter season on record (NOAA, 2008) and the 1998-99 season represents the highest average winter temperature ever recorded for the third of three consecutively above average seasons.

It can be inferred that anomalies that occurred in ski resort operations during the analogue seasons may in turn become normal operating conditions in the 2040-69 time period if temperatures rise in the region as projected under some climate change scenarios. Regional ski area information including, ski season length, snowmaking requirements, visitation and operating profits, from the analogue years are compared with ski area information from the 2000-01 and 2004-05 seasons, which are representative of climatically average conditions for the region over the 1961-90 baseline period.

The climatic average (2000-01 and 2004-05) seasons used in this study were chosen from winter climate data from the past 12 years which best represent the 1961-90 climatic average (temperature and precipitation) for winter seasons (December – February) (NOAA, 2008). These seasons represent the second and third best representations of an average season in the region for the past 112 years. The absolute best climatologically average year actually occurred 20 years ago in 1987, prior to the large-scale regional expansion of snowmaking, which was not complete until the mid to late 1990s. Because snowmaking is an integral part of ski area operations today, the climatically normal year, 1987 was not used in this study as it would not be directly comparable to current standard operating conditions in the study area. Furthermore, other major factors influencing ski business were different 20 years ago (e.g. ski participation rates, interest rates, travel costs, ski business models). Since the mid-1990s, ski area business models have stayed reasonably consistent (i.e. heavy real estate development, diversified revenue sources, establishment of conglomerates), therefore allowing for a more reliable comparison between marginal and average ski area performance in this timeframe. Normal baseline years were selected as close to the analogue years as possible in order to minimize the influence of other major factors that affect the ski industry over one to five year timeframes (e.g. general economic conditions, fuel prices, new competitors, growth-recession, interest rates). By carefully selecting baseline years for comparison, the influence of climate variability is isolated as much as possible. However, the extent to which other major influencing business factors have been controlled for through this method remains uncertain.

In this study, ski area performance indicators for the 2001-02 (high emission) and 1998-99 (mid-range emission) analogue years were compared with indicators for the climatically normal (for 1961-90) years of 2000-01 and 2004-05. Ski area size, measured by capacity (vertical transport feet per hour – [vtf/h] from NSAA), was also analyzed outlining the range of climate change vulnerability differences between small (0-2,999 vtf/h), medium (3,000-5,999 vtf/h), large (6,000-11,999 vtf/h) and extra-large (12,000 + vtf/h) ski areas. Finally, the revealed impact during the climate change analogue years (1998-99 representative of a 2040-69 mid-range emissions scenario and 2001-02 representative of a 2040-69 high emissions scenario) were compared with previously modeled season length data for the 2040-69 time period in the US Northeast region (modeled data found in Dawson & Scott 2007 and Scott et al. 2008).

2.3 Results

The results of the study are divided into three segments, comparing the physical indicators (snowfall, season length, and snowmaking requirements), demand indicators (skier visitation) and economic indicators (operational profit) between the analogue years and climatically normal years.

2.3.1 Physical Indicators

Four physical indicators were examined including, natural snowfall in inches (as reported by ski areas, not climate stations), snowmaking hours, percentage of power utilized for snowmaking and ski season length. During the climatically normal years of 2000-01 and 2004-05, the average snowfall at ski areas in the US Northeast region was reported to be 176 inches. During the analogue seasons of 1998-99 (consecutive season mid-range analogue for 2040-69) and 2001-02 (single season high emissions analogue for 2040-69) only 108 and 107 inches of natural snow respectively fell, leaving ski areas with almost 40% less natural snow than during climatically average seasons.

Less natural snowfall during the analogue years forced ski areas to rely more heavily on snowmaking to make up for poor snow coverage particularly early in the season. Snowmaking hours increased by 75.8% and 11.4 % in the 1998-99 and 2001-02 analogue seasons respectively, in comparison to the climatically average years. The significant increase in snowmaking hours during the 1998-99 three-season analogue in comparison to the 2001-02 single-season analogue is likely due to a combination of factors. In the 1998-99 season, precipitation and percent of precipitation falling as snow was well below average in the months of November and December. The 2001-02 season saw below average snowfall during these months but not as severely below average as the 1998-99 season. Due to low early season snowfall ski area operators likely increased snowmaking hours during this very important portion of the ski season to ensure there was a sufficient base to open for, and avoid any unwanted closures, during the economically important Christmas/New Year holiday period. Additionally, during the month of December of the 2001-02 season average temperature for the region was only -1.5°C (29.3°F) which meant there were relatively few periods with extended temperatures of at least -5°C (23°F) or cooler, which is required for efficient snowmaking (see Scott et al. 2003). With a high probability of losing machine-made snow to warm daytime temperatures and liquid precipitation events many ski areas would not even attempt to make snow at lower elevations thereby reducing snowmaking hours. Finally, the increased snowmaking hours increased the amount of power utilized for the purpose of creating snow by 37% (1998-99) and 31% (2001-02) in comparison to average ski seasons. The fact that snowmaking hours increased so dramatically during the 1998-99 season in comparison to both the average season and the single-season analogue, but the percent power utilized for snowmaking did not increase proportionally also suggests that snowmaking capacity or snowmaking efficiency may have increased between 1998 and 2002.

The limited natural snow cover and increased snowmaking that occurred during the 1998-99 and 2001-02 US Northeast ski seasons also had an effect on average ski season length. Season lengths were 3.4% (1998-99) and 10.9% (2001-02) shorter than during average seasons, totaling an average season reduction of almost two full weeks for the high emissions analogue. Season length loss that occurred during the first and second seasons of the three season analogue period (1997-99) was slightly greater totaling reductions of 6.4 and 7.2% (Table 3).

Table 3: Physical indicators (average and analogue)

Indicators	Average of climatically Normal Years	Climate Change Analogue Years		%change 1998-99*	%change 2001-02**
	2000-01 & 2004-05	1998-99	2001-02		
natural snowfall (inches)	176	108	107	-38.6	-39.2
snowmaking (hours operated)	930	1635	1036	+75.8	+11.4
snowmaking % power utilized	40	54	52	+36.7	+31.4
season length (days)	132.5	128	118	-3.4	-10.9

* mid-range climate change analogue scenario for 2040-69 (ccsmB1)

** high emissions climate change analogue scenario for 2040-69 (ccsmA1B)

When examining the differential vulnerability of ski areas, season length was found to be positively correlated with size of resort. The NSAA uses vertical feet per hour (vtf/h) as a measure of a ski area's capacity to transport skiers to the top of the slopes, thus indicating relative size. Small resorts are defined as those with less than 2,999 vtf/h, medium resorts as those with 3,000-5,999 vtf/h, large with 6,000-11,999 vtf/h and extra-large with 12,000+ vtf/h (NSAA, 2007). The smaller resorts consistently experienced the greatest loss in season length during both analogue years followed by medium, large and then extra-large ski areas (Table 4).

Table 4: Season length differences when considering size of resort

Indicators	Average of Climatically Normal Years	Climate Change Analogue Years		%change 1998-99*	%change 2001-02**
	2000-01 & 2004-05	1998-99	2001-02		
Small	109	99	87	-9.2	-20.2
Medium	132	125	119	-5.3	-9.9
Large	139	135	133	-2.9	-4.3
Extra Large	160	173	153	+8.3	-3.8

* mid-range climate change analogue scenario for 2040-69 (ccsmB1)

** high emissions climate change analogue scenario for 2040-69 (ccsmA1B)

2.3.2 Demand Indicators

Marginal snow conditions and shortened season lengths are observed to have an impact on ski area visitation. During the 2000-01 and 2004-05 average ski seasons, US Northeast ski areas drew more than 13.5 million skier visits. Visitation during the climate change analogue seasons of 1998-99 and 2001-02 drew 10.8% and 11.6% fewer visits respectively (Table 5).

Table 5: Demand indicator (average and analogue)

Indicators	Average of Climatically Normal Years	Climate Change Analogue Years		%change 1998-99*	%change 2001-02**
	2000-01 & 2004-05	1998-99	2001-02		
number of skier visits	13,789,002	12,299,495	12,187,577	-10.8	-11.6

* mid-range climate change analogue scenario for 2040-69 (ccsmB1)

** high emissions climate change analogue scenario for 2040-69 (ccsmA1B)

2.3.3 Economic Indicators

The combination of increased snowmaking costs, decreased season lengths and lower visitation rates, inevitably increases operational costs for power/fuel, labour and machine maintenance and reduces revenues from lift passes as well as other related spending (i.e. ski rentals, lessons, food and beverage and accommodation). Examination of available economic data for the US Northeast region shows that operating profit as a percent of gross fixed assets (gfa) (i.e. excluding depreciation and/or amortization) display almost no change for the 1998-99 climatically marginal season (2040-69 mid-range analogue). Over the three seasons analyzed as the multiple season analogue in this study, operating profit losses decreased each year despite similarly difficult climatic conditions. During the 1996-97 season operation profit loss totaled 14.5%, increasing to a loss of just 8.1% in 1997-98 and a gain of 2.4% in 1998-99. This linear increase reflects a possible learning progression whereby operators learned to work within a set operating budget despite marginal snow conditions.

During the 2001-02 climatically marginal season (2040-69 high emission analogue) there was a significant decrease in operating profit (%gfa). This season experienced average winter temperatures 7.5°F higher than climatically normal temperatures for the 1961-90 baseline period, greatly increasing the necessity for snowmaking and the concomitant cost of snowmaking during this anomalously warm season. Operating profits were 33% lower than during a climatically average season (Table 6). It is important to note that while these represent substantial reductions, the ski industry as a whole still operated in a profitable position in the region.

Table 6: Economic indicators (average and analogue)

Indicators	Average of Climatically Normal Years	Climate Change Analogue Years		%change 1998-99*	%change 2001-02**
	2000-01 & 2000-05	1998-99	2001-02		
operating profit (% gross fixed assets)	13	13.1	8.6	+2.4	-32.6

* mid-range climate change analogue scenario for 2040-69 (ccsmB1)

** high emissions climate change analogue scenario for 2040-69 (ccsmA1B)

Declines or increases in specific revenue sources during the analogue years were also examined. During the mid-range analogue for the 2040-69 period (1998-99) lift ticket sales decreased by nine percent, food and beverage decreased by just over five percent, equipment rentals decreased by 20% and retail increased by three and one half percent. During the high emissions analogue for the 2040-69 period (2001-02) lift ticket sales remained very close to average (+2%), suggesting skiers adapted to poor early season conditions and visited more frequently in mid to late season. Other revenue areas were affected differently, with food and beverage decreases of almost eight percent, equipment rental decreases of one percent and retail increases of almost eight percent. It is difficult to conclusively say why these revenue sub-sectors were impacted differently. However, it is possible that skiers who normally ski full days instead skied for half days during the marginal conditions therefore decreasing food and beverage profits. Marginal conditions may have also enticed skiers to participate more in shopping-based activities instead of skiing.

When examining the differential vulnerability of ski areas, correlation between operating profits was less clear than observed for season length. This data suggests that medium and large ski areas generally fair better economically during climatically marginal winter seasons than small or extra-large ski areas (Table 7).

Table 7: Operating profit (%gfa) differences when considering size of resort

Indicators	Average of Climatically Normal Years	Climate Change Analogue Years		%change 1998-99*	%change 2001-02**
	2000-01 & 2004-05	1998-99	2001-02		
Small	14.5	10.5	8.7	-27.7	-40.4
Medium	11.2	11.6	11.7	+3.5	+4.6
Large	9.7	10.0	8.0	+2.5	-17.4
Extra Large	16.4	14.4	7.9	-12.4	-51.5

* mid-range climate change analogue scenario for 2040-69 (ccsmB1)

** high emissions climate change analogue scenario for 2040-69 (ccsmA1B)

Note: Small = 0-2,999 vtf/h (000's); Medium = 3,000-5,999 vtf/h (000's); Large = 6,000-11,999 vtf/h (000's); extra-large = 12,000+ vtf/h (000's) (NSAA, 2007).

2.4 Discussion

In this study an analogue approach was used to examine a variety of physical, demand and economic impacts experienced by ski areas in the US Northeast region during unusually warm winters that are anticipated to be representative of average climatic conditions in the future. The discussion focuses on two key areas; including the differences found between a single warm season (single season analogue – 2001-02) and consecutively warm season impacts (three-season analogue – 1998-99), and the differential impacts among the size of ski areas.

2.4.1 The Impact of High Emissions Single Season versus Mid-range Emissions Consecutive Season Analogues

The 1998-99 season was chosen to represent a mid-range analogue for the 2040-69, and is an example of the third of three consecutively marginal ski seasons. The three seasons occurring between 1996-97 and 1998-99 all experienced average temperatures of at least 4.5°F above the 1960-91climatic average. Results indicate that during the third warm season (1998-99), ski areas experienced significant increases in snowmaking hours (+75%) and costs (+37% power required), a shortened ski season (-5 days), and an 11% loss in visitation, but still managed to produce a profit at the regional level. In this example of consecutively marginal seasons, ski areas appear to have adapted well to warmer conditions, likely having learned from experience in the two previous warm winters (i.e. evidenced by progressively increased operating profit over the three seasons). Revenues per skier visit during the 1998-99 season were almost five dollars higher per person than seen in average years (in-part due to increased shopping-based activities), which partially explains the slight increase in operating profit despite decreased ticket sales and visitation combined with increased snowmaking costs. Revenue generated from rental equipment was significantly impacted during this season (-20%), suggesting that fewer new/beginner skiers participate in skiing during years with marginal snow conditions.

Ski area operators do not appear to have adapted as well to marginal conditions during the 2001-02 record warm season. During the 2001-02 season ski areas were forced to increase snowmaking requirements by 12% (hours operated), causing a 31% increase in power utilized for snowmaking, season lengths decreased by 15 days, visitation was down by almost 12% and operating profits declined by as much as 32%. The greater impacts felt can be attributed to worse climatic conditions (high emissions analogue for 2040-69 time period) and perhaps to ski areas being less prepared than in the 1998-99 season, which was the third consecutive poor season.

2.4.2 Differential Vulnerability among Ski Areas

In their analysis of the climate change vulnerabilty of the US Northeast winter recreation-tourism sector, Scott et al., (2008) concluded that it is not the entire ski industry in the region that is at risk to climate change but rather individual ski businesses and communities that rely on ski tourism. This is because individual ski areas have a range of technical snowmaking capabilities, are situated at varying elevations and have different business models (i.e. are of different sizes, provide winter vs. 4 season activities, have different ownership structure and access to capital). The majority of ski areas in the Northeast have substantial snowmaking capabilities, meaning that the few that do not, are significantly disadvantaged and will require substantial investment in order to survive under projected warmer future climatic conditions. Ski areas located at higher elevations in the US Northeast are inherently at an advantage due toa lower mean temperatures and greater proportion of winter precipitation as snowfall. Ski areas situated at higher elevations experience fewer marginal natural snow conditions and are able to produce machine-made snow more often and at lower costs than lower lying ski areas (i.e. machine-made snow typically requires temperatures of 23°F (-5°C) or colder to be produced effeciently – Scott et al., 2003). Finally, medium to large ski areas can be at an advantage as they can usually support a larger client base on any operating day, therefore generating higher revenues. They also typically have multiple activities, including indoor, non-snow reliant activities for visitors to engage in when snow conditions are poor. Furthermore, larger ski areas in the US Northeast region generally are situated at higher elevations than smaller ski areas.

In this study, key indicators (season length and operating profit) were analyzed by size of resort, as defined by vertical transportation feet per hour (vtf/h). Season length was found to be influenced by the size of a ski area. For example, the smaller the ski area the more significant the loss in season length that can be expected during future warning regimes. A size-based correlation for economic indicators was less clear; likely a result of the different acumen and decisions made by different ski area operators. Medium and large ski areas generally fair better during climatically marginal winter seasons than small or extra-large ski areas. This finding may be because some lower lying small resorts do not have sufficient snowmaking investments making it difficult for them to stay operational for the duration of a marginal season. Extra-large ski areas may struggle to keep a larger area operational and may in doing so, require significant expenditure because of increased snowmaking requirements in comparison to medium or even large sized ski areas. In addition extra-large ski areas may have less flexibility with personnel and may be unable to temporarily lay people off. Differential vulnerability among ski areas noted in this study suggest that small ski areas, located at low elevations are the most likely to experience the greatest impact from future climatic change.

2.5 Conclusion

The objective of this research was to examine climate change vulnerability of the US Northeast ski tourism industry using an historic analogue approach. Using mid-range and high emissions analogues for the 2040-69 time period, it was revealed that under anticipated climate change conditions ski areas will, in the future, experience substantial impacts including increased snowmaking requirements and costs of operation along with decreased visitation and operating profits. However, adaptation measures look promising for the ski tourism industry not only because they have access to technologies that will aid in operation (i.e. snowmaking) but also because the third-consecutive season analogue suggests business decisions and adaptation measures implemented early are successful in reducing the impacts of consecutive season impacts during marginal conditions similar to those expected during a mid-range analogue in this study.

Analogue data suggests that the lowest, smallest and extra large resorts are more vulnerable than medium and large sized resorts and as a result may incur higher adaptation costs than the latter. In the future, ski areas that are able to afford the cost of adapting to climatic changes expected over the next three to five decades are most likely to survive. The analogue data suggests that even higher adaptation costs should be expected by all ski area operators in the region under the high emissions scenario for the 2040-69 time period. This is generally consistent with modeling-based studies in the region. Importantly, adaptations by ski businesses appear to have reduced the impacts of warm winters, as season length reductions in the climate change analogue years were consistently lower than those projected in modeling-based studies.

An analogue for a 2070-99 time period was not available for the US Northeast region, therefore the use of an analogue to examine the impacts expected to occur in this future timeframe was not possible. Because the industry has not yet experienced temperatures similar to those projected for 60-90 years from now, a modeling approach remains an important method for examining long-term impacts. Combining information available from an analogue assessment with modeled data is likely to be the most useful approach in understanding the net climate change vulnerability of the ski tourism industry.

Future analogue-based research within the ski tourism sector will provide a clearer picture of the effectiveness of adaptation in different parts of the US and elsewhere. Specifically, future research might include calibrating the demand and profit indicators with season length, in order to provide greater understanding of the implications of season lengths projected in model-based studies. A more detailed analysis of indicators based on the size of ski resorts at an individual ski business scale (i.e. Killington Resort versus Sugarbush Resort) would be fruitful in determining which ski areas are more or less vulnerable to climate change and would allow for a more specific determination of how the regional ski marketplace may evolve over time. Determining where the ski industry might contract and which communities may need to prepare to adapt to the related economic loss, as well as which communities may need to prepare for development pressures (e.g. water use for snowmaking, real estate development, slope expansion, congestion) associated with the concentration of ski tourism in fewer areas, should also be a priority for future research.

Chapter 3: Modeling Climate Change Impacts on Ski Season and Snowmaking in the US Northeast

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 examines supply-side vulnerability of the alpine skiing industry (n=103 ski areas) under six climate change scenarios for the 21st century. It builds on the ski operations modeling approach developed by Scott et al. (2003, 2006, 2007), which is able to account for snowmaking, a climate adaptation universal to ski areas in the region. Under all scenarios, natural snow becomes an increasingly scarce resource, causing changes in ski-season length, snowmaking requirements and probability of ski areas being operational during economically important holiday periods. By mid-century less than 30% of ski areas in the region were projected to maintain an average ski season greater than 100 days under a low emission scenario (B1) and fewer than 40% under a high emissions scenario (A1fi). Snowmaking requirements increased by 9% (mid-range) and 40% (high emissions) in this timeframe, and probability of being operational during holiday periods decreased by 35 and 26% respectively. The results indicate a northwards contraction of the ski industry toward northeastern New York, Vermont, New Hampshire and Maine by mid-century. Ski areas in Connecticut and Massachusetts are expected to experience the most severe impacts of climate change, with no ski areas in these states projected to remain in operation by mid-century.

Keywords: ski tourism, climate change, vulnerability, Northeast US, impacts

3.1 Introduction

Weather and climate are intrinsic components of the tourism experience, influencing tourist demand, comfort and satisfaction as well as tourism operations (e.g. water supply, energy costs, insurance costs) and environmental resources critical to the industry (e.g. glaciers, biodiversity, water levels, snow). A changing climate has the potential to significantly influence this economically important and climate-sensitive sector. Due to its growing importance, the literature on the interactions of climate change and tourism has increased rapidly in recent years, doubling between 1995-99 and 2000-04 (Scott et al., 2005). Despite this increase, many authors still express concern that understanding of the potential impacts of climate change for the tourism sector remains limited (UNWTO-UNEP, 2003; Scott, 2005; Gössling & Hall, 2005). This concern was clearly echoed by the United Nations World Tourism Organization, the United Nations Environment Program and the World Meteorological Organization which identified climate change as the '*greatest challenge to the sustainability of the global tourism industry in the 21st century*' (UNWTO-UNEP-WMO, 2008).

The winter tourism sector, and in particular the ski industry, has been earmarked as one of the most vulnerable industries to climatic change (UNWTO-UNEP, 2003; UNWTO-UNEP-WMO, 2008). Bicknell & McManus (2006) highlighted the ski sector as a 'canary in the coalmine', and suggested the first signs of change are being witnessed directly within the industry. König & Abegg (1997) revealed that the ski industry in the Swiss Alps is still feeling the impact of snow-deficient winters from the 80s and project that a change in climate by as little as +2°C could influence a decrease in snow coverage causing a reduction in the number of 'snow reliable' ski resorts (i.e. ski areas with at least 100 day seasons and a minimum of 30 cm snow cover) from 85% to just 63%. In this scenario, the line of snow reliability is expected to rise from 1,200 metres above sea level [masl] to 1,500 masl. Elsasser & Bürki (2002) examined a potential rise in the snow line to 1,800 masl finding a reduction in the number of 'snow reliable' ski resorts to just 43% of those operating currently. Behringer et al. (2000) examined the influence of anticipated marginal future snow conditions on ski area demand in Switzerland indicating that 49% of skiers would decide to ski at another ski areas with more reliable snow, 32% would ski less often and 4% would give up skiing altogether.

In Austria, Breiling & Charamaza (1999) demonstrated that ski areas at lower elevations are particularly vulnerable to climate change. This has been supported in several other studies (i.e. Abegg et al., 2007; Dawson & Scott, 2007; Scott & McBoyle, 2007; Scott et al., 2007) and has lead to the commonly cited future climate change adaptation strategy of moving ski areas to higher elevations

(Scott & McBoyle, 2007). More recently, Abegg et al. (2007) examined natural snow reliability in Austria, France, Germany, Italy and Switzerland. Under current climate conditions, 609 of the 666 ski areas (91%) examined are currently 'snow reliable'. Under a scenario of +1°C the number of snow reliable ski areas drops to 500; under a +2°C scenario this drops to 404 and under a +4°C scenario the number of snow reliable ski areas drops to 202. Germany is expected to experience the most significant impacts (60% reduction under 1°C scenario) and Switzerland the least (10% reduction under 1°C scenario). The only known study to assess climate change vulnerability in the European ski sector outside the Alps is Moen & Fredman (2007) who examined the alpine ski sector in Sweden projecting a reduction in skier days of between 64 and 96 for the 2070-99 time period.

Australian studies show similar results including estimates of reduced snow-reliable days by between 60 and 75 in a single season (Galloway, 1988; Whetton et al., 1996). Hennessy et al., (2003) examined the impact of climate change on natural snow cover finding that the average snow-reliable ski season length would be reduced by between 5 and 40 days in the 2020s, but also estimated that the impact could be significantly offset with machine-made snow. König (1998) examined behavioural adaptation of skiers at three ski areas in Australia finding that under marginal snow conditions 25% would ski less often, 38% would ski elsewhere and 4% would quit skiing.

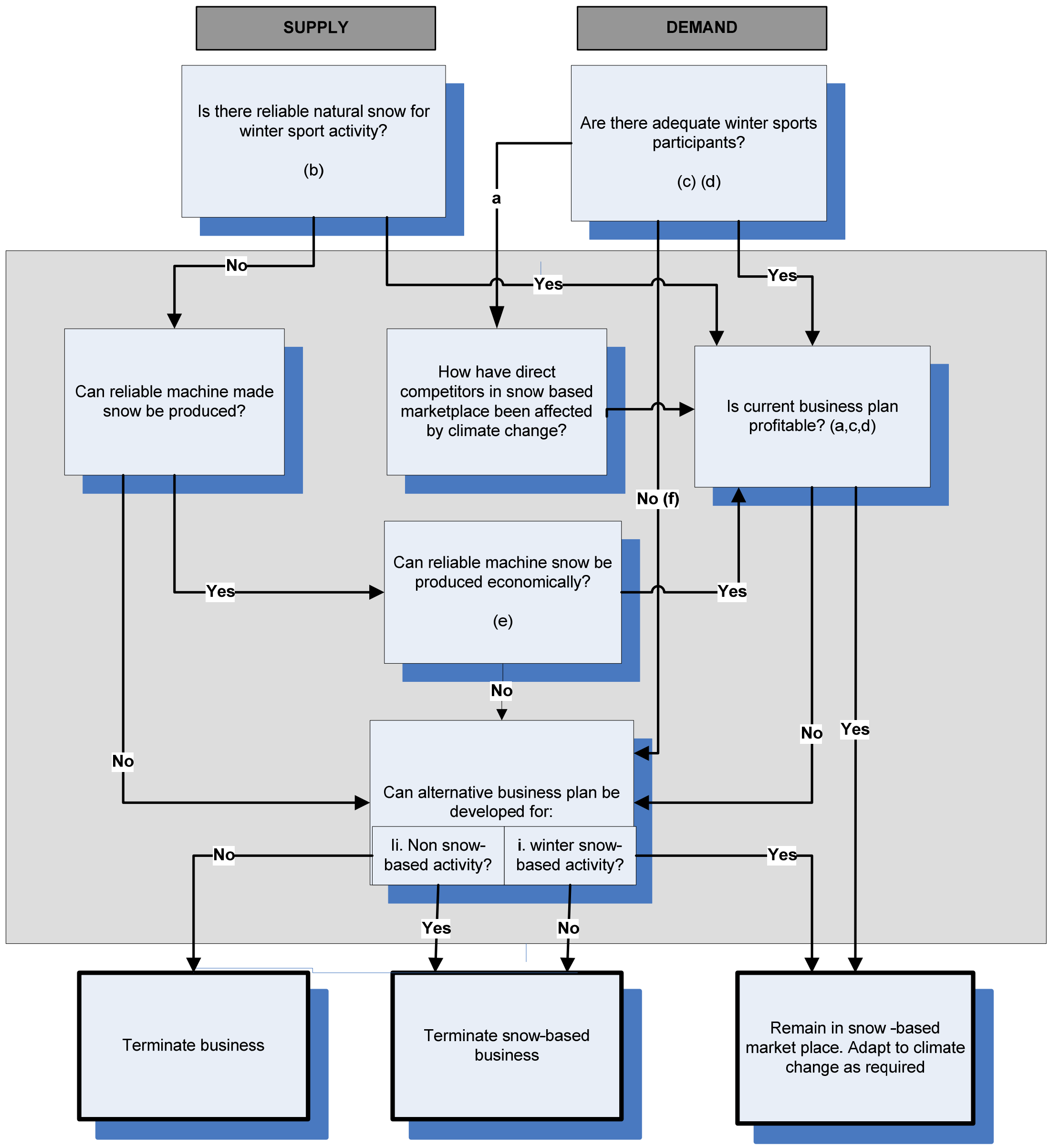
The earliest studies examining the impact of climate change on the North American ski sector were conducted in the Great Lakes region. McBoyle et al., (1987) used climate change scenarios available at the time (doubling of atmospheric CO_2), projecting ski season length reductions of between 30 and 40% for a region on the north shore of Lake Superior. Ski seasons were projected to also be curtailed in the southern Great Lakes region near Georgian Bay by between 80 and 100%. Ski season length in the Lower Laurentian Mountains of Quebec was projected to decrease by between 40 and 89% (McBoyle & Wall, 1992) and skiable days in southern Quebec were estimated to decline 50-70% (Lamothe and Périard Consultants, 1988). Lipski and McBoyle (1991) examined ski season length in Michigan projecting reductions of between 30 and 100%. In a study of the same region Shih et al. (2009) found that during past ski seasons one additional inch of snow depth increased ticket sales by between 7 and 9% and that the reduction of snow depth expected under future time periods would result in a more significant decrease in future ticket sales.

The economic implications of climate change for the international ski industry could be profound. However, Scott et al. (2003, 2006a, 2007) suggested that many of the 'first generation' studies (i.e. those listed above) examining climate change vulnerability for the ski sector likely overestimate the potential future impacts by not considering the widely used adaptation of snowmaking. Scott et al. (2003) were the first to include a snowmaking module in their analysis of climate change impacts on ski tourism in Ontario. Findings suggest ski season lengths are expected to decrease by 1–13% in the 2020s and 7–23% in the 2030s. These estimates describe significantly less impact than those made in similar regions by McBoyle et al. (1986), McBoyle and Wall (1987), Lamoth and Périard Consultants (1988), and Lipski and McBoyle (1991) who projected declines ranging from 30–100%. Recent studies in eastern North America have also projected increases in snowmaking requirements and decreasing probability of being operational during the economically important Christmas holiday period (see Scott et al. 2003, 2006a,b, 2007, 2008; Dawson & Scott, 2007).

The most significant limitation of the climate change and ski tourism literature, to date, has been the absence of snowmaking in empirical assessments of supply-side impacts (see Scott et al., 2003). Scott et al., (2008) suggested that a second considerable limitation includes the lack of understanding regarding the likely contraction of the ski sector including the impacts that this may have on operators and nearby communities. The slow contraction of the ski sector is not a new phenomenon in North America. For example, a series of marginal snow years throughout the late 80s and early 90s' is thought to have in part contributed to permanent closures of 592 ski areas in the US Northeast region between 1980 and 2008 (NELSAP, 2008). A significant proportion of these 'lost ski areas' were small-scale privately owned and operated family business and in some cases small seasonal hobby businesses that were often located on family-owned lands. The change in snow conditions necessitated large investment in snowmaking technology and equipment that many small family businesses could not afford. Considering some of the remaining ski areas in North America remain privately owned, and climate change is likely to influence a further increase in temperature, an exacerbation of the historic contraction of the ski sector, at least in North America, seems very plausible – both due to increased climate variability and fluctuating economies.

Another limitation of the climate change and ski tourism literature is that the majority of studies currently fail to reveal the potential contraction of entire regional ski sectors by neglecting to evaluate each individual ski area within an entire ski area marketplace. According to Scott et al., (2008) it is not the entire ski market that is at risk to climate change, but rather at risk are individual ski areas that are not able to afford the increased costs of adapting to projected change. Two known acceptations include Scott et al. (2006a, b) who examined a select few locations in Ontario and Quebec, Canada to examine climate change vulnerability and Abegg et al., (2007) who evaluated and compared vulnerability disparities between countries in Europe. Failing to examine an entire marketplace means it is difficult to understand the regional implications that vulnerability at one ski area could mean for an adjacent ski area, for the regional ski marketplace, or for communities and individuals reliant on the sector generally. The implications of climate change have been shown to vary substantially by market segment and geographic region, and will likely in part depend on the impacts experienced by competitors. Figure 1 outlines a decision making flowchart that ski area managers can negotiate while considering the impact that climate change may have for both ski area supply and demand. Not only are billions of industry dollars at risk, the communities and individuals that rely on ski tourism will also be significantly impacted under projected warming conditions. All tourism destinations will need to adapt to climate change in order to minimize risks and capitalize on new opportunities in an economically, socially, and environmentally sustainable manner. A negative impact in one part of the tourism marketplace may constitute an opportunity for destinations elsewhere. In order to adapt effectively to future conditions each ski area operator will need to determine if they should invest in adaptations that will aid in continuing a snow-based business, if they need to invest in adapting and evolving into a non-snow-based business (i.e. 4-season resort, spa, conference centre), or if they need to terminate their business altogether. Figure 1 outlines a flowchart[2], developed for ski operators, to aid this decision making process. The implementation of a systems-based approach as well as input from individual ski area operators is required in order to negotiate the flowchart as both supply-side and demand-side impacts require analysis as well as other factors such as economic and cultural influences. For example, it is important to first know if there is reliable snow for ski activity, if reliable snow is expected in the future, if there are adequate participants now, and if there will be in the future. Other relevant questions include: can reliable machine-made snow be produced? can this snow be produced at a reasonable cost? how have direct competitors in snow-based business been impacted by climate change (i.e. how have competitors adapted to current changes)? is the current business model profitable? can an alternative business-model be developed for either snow-based activities or non-snow-based activities?

[2] The Management Decision Making Flowchart was developed collaboratively by the author, Dr. Daniel Scott and Dr. Geoff McBoyle. It has been included in an article titled “Climate change analogue assessment of the US ski sector’ to be submitted to *Tourism Management*.



a) Marketplace competition is likely to decline according to existing literature. If demand remains stable or dilutes proportionality less than supply, there would be a net transfer of demand throughout the remaining marketplace.
b) Are necessary 'natural' climate conditions present
c) numbers could stabilize or increase if there were increases in travel costs or emission rights
d) numbers could decrease because of changing demographics (aging and multi culturalism); social trends; climate variability; and cost
e) direct operator costs – capital investments for snowmaking systems and their upgrades; increased operating costs (energy, water, labour) of snowmaking if more snow needed at higher temperatures. Also consider indirect economic changes – changes in skier demand, marketplace, and market share.
f) examine alternative marketing plans to increase participation rates

Figure 4: Climate change management decision making flowchart for ski area operators

This study examines climate change vulnerability for all of the 103 operating ski areas in the US Northeast ski area marketplace and evaluates the potential future contraction of the industry. The research builds on the recommended methods of Scott et al., (2003), which include snowmaking in an empirical assessment of three main factors; ski season length, snowmaking requirements and probability of being operational during the economically critical Christmas-New Year holiday.

3.2 Methods

3.2.1 Study Area

This study examines ski areas located in the Northeast region of the US (as defined by the National Ski Area Association - NSAA), which includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (Figure 5). There are approximately 103 ski areas currently operating in the region, including small and large scale resorts located at both low and high elevations, which range from 137 metres above sea level [masl] to 1353 masl (Figure 1). Just over 8% of the US population (15.5 million people) participates in snow-based recreation (including alpine skiing, Nordic skiing, snowboarding and snowshoeing, but not snowmobiling) and the highest participation rate across the country is in the Northeast region. There have been over 13 million annual skier visits recorded in the US Northeast region for the past several years (NSAA, 2005, 2006a, 2007). The ski tourism sector in the state of Vermont alone contributes over US$1.5 billion to the annual state economy and creates over 13,000 jobs (VSAA, 2004).

Since 1900, annual temperature across the US Northeast has increased an average of 0.08°C (0.14°F) per decade and from 1970 to 2002 the region experienced warming at a higher average rate of 0.28 °C (0.5°F) per decade (Hayhoe et al., 2006). Warming that has been projected under some climate change scenarios for the 2010-39 time period has already been realized in some areas of the US Northeast (Hamilton et al., 2007). Hayhoe et al., (2006) project an increase in average regional temperature between 2.9°C and 5.3°C by the 2070-99 time period relative to the 1961-90 baseline under a low (B1) and high emissions scenario (A2).

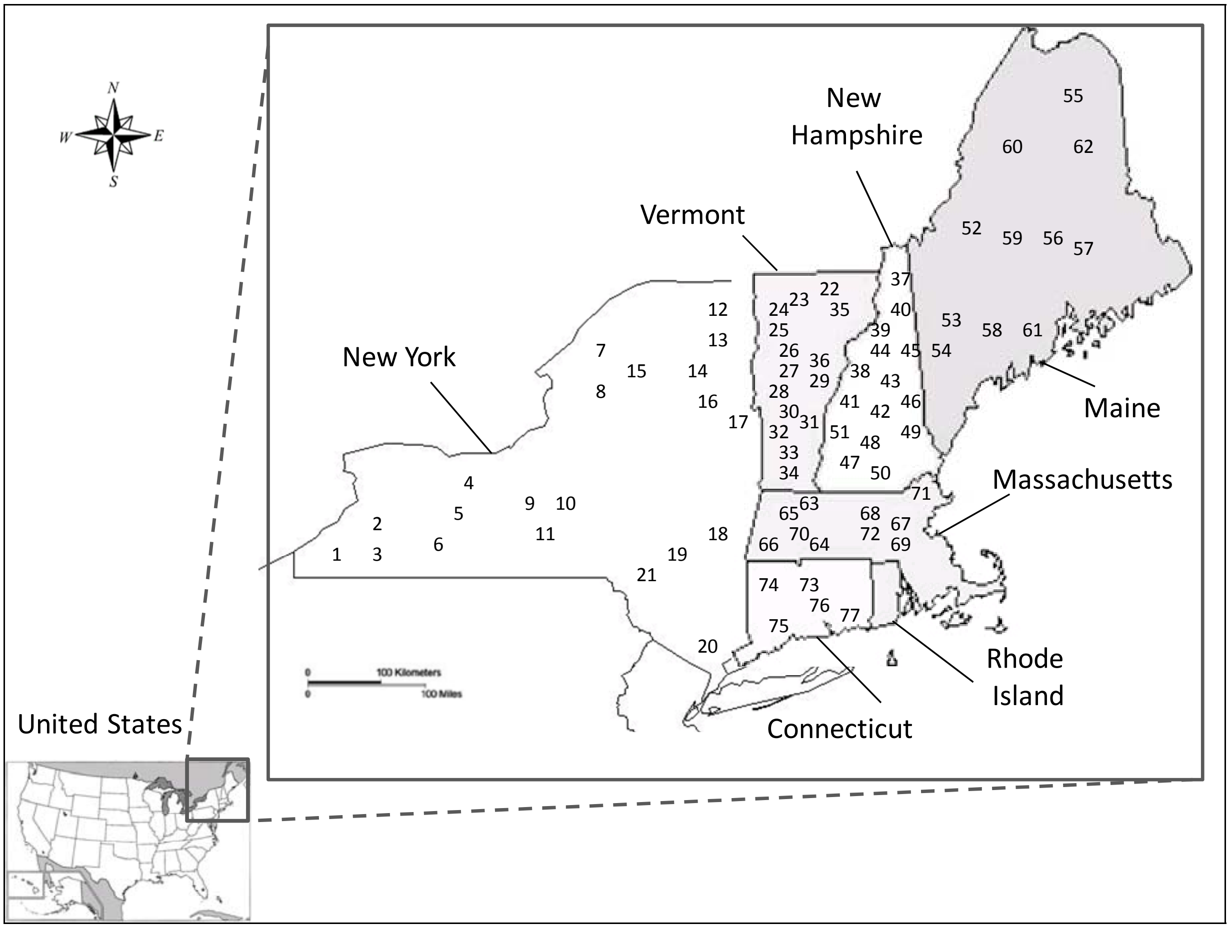


Figure 5: Map of US Northeast ski areas

New York (n=36): 1-peek n' peak, 2-cockainge, holiday valley, holimount, 3-kissing bridge, 4-brantling, 5-bristol, 6-swain, 7-dryhill, 8-snowridge, woods, 9-song, 10-four seasons, labrador, toggenburg, 11-greek peak, 12-whiteface, 13-gore, 14-oak, 15-mccauley, titus, 16-royal, 17- hickory, west, willard, 18- catamount, cortina, hunter, sawkill, 19-belleayre, platekill, whindam, 20, mt peter, stirling, 21-bobcat, holiday mountain
Vermont (n-18): 22-jay peak, 23-smugglers notch, 24-bolton valley, stowe, 25-cochran, 26-madriver, 27-middlebury, 27-killington, pico, 29-sugarbush, 30-okemo, 31-ascutney, 32-bromley, 33-magic, stratton, 34-mt snow, 35-burke, 36-suicide six
New Hampshire (n=18): 37-balsams, 38-cannon, loon, 39-bretton, 40-black, wildcat, whaleback, 41-dartmouth, 42-tenney, 43-watterville, 44-attiash, 45-cranmore, 46-king pine, 47-sunapee, 48-ragged, 49-gunstock, 50-pats peak, 51 -crotched
Maine n=14): 52-saddleback, sugarloaf, 53-black, mt abram, sunday river, 54-shawnee, 55-big rock, 56-eaton, 57-new hermon, 58-lost valley, 59-titcomb, 60-big squaw, 61-camden, 62-mt jefferson
Massachusetts n= 12): 63-berkshire, 64-blandford, otis, 65-jiminy peak, 66-butternut, 67-nashoba, 68-pine ridge, wachusett, 69-blue hills, 70-bousquet, 71-bradford, 72-ward
Connecticut (n=5): 73-sundown, 74-mohawk, 75-woodbury, 76-southington, 77-powder ridge

3.2.2 Climate Change and Ski Area Operations Modeling

Future climate change scenarios and the baseline period (1961-90) used in this study were derived from gridded climate data (daily temperature and precipitation at 1/8° resolution) supplied by the Northeast Climate Impact Assessment [NECIA] (see NECIA, 2007; Hayhoe et al., 2006; Frumhoff et al., 2008). Six climate change scenarios were utilized to project impacts for three future time periods (i.e. 2010-39, 2040-69 and 2070-99). Three different Global Climate Models [GCM] (HadCM3, PCM, GFLD) (see glossary of terms, p. xi) were each run under two IPCC-SRES emission scenarios (see glossary of terms, p. xi), representing a high emissions future (A1Fi - 970 ppm) and a relatively low emissions future (B1 - 550ppm) (IPCC, 2000). These climate change scenarios are consistent with those used in the Northeast Climate Impact Assessment (Union of Concerned Scientists, 2006). Additional information on scenario selection and methodological details of scenario construction are described in Hayhoe et al., (2006) and Frumhoff et al., (2008). The GCMs were specifically chosen for that assessment and also for this study because of their superior performance in reproducing historic climate in the region relative to other GCMs (see Hayhoe et al., 2008).

Ski operations were modeled using the 'ski-sim' model developed by Scott et al. (2003; 2006; 2008), which is used to project future ski season length, snowmaking requirements and probability of being operational during economically important holiday periods. The major refinement to the 'ski-sim' model in this analysis was the addition of elevation adjustments for each ski area based on its mid-point elevation (peak-base/2). The model was otherwise run consistently with previous studies in Ontario (Scott et al. 2003, 2006a) Quebec (Scott & McBoyle, 2006b) and Vermont (Dawson & Scott, 2007) to allow for comparison of results. Conclusions are made about which ski areas are more vulnerable than others under different time horizons and under a range of future climate change scenarios. The extent to which individual ski areas are considered economically vulnerable is determined using two factors; 75% probability of being operational during the economically vital Christmas-New Year holiday (i.e. open for full period seven and a half years out of ten), and the '100-day rule' (König & Abegg, 1997; Bürki, 2002; Erickson, 2005), which has been suggested to be an indicator of profitability in Europe and North America (Abegg, 1997; Scott et al., 2003). Projections are made about where the industry might contract to under different future climate change conditions.

Ski areas across the US Northeast range significantly in elevation meaning that average temperature at different ski areas can vary considerably. To account for the different temperatures at varying elevations for individual ski areas, vertical adjustments using a generic lapse rate of + 0.65°C per 100 m of elevation were made to the temperature data, which represents the average elevation for the area. The elevation of each ski area was represented by its mid-range elevation (summit – base / 2), which is consistent with the approach used in the most comprehensive analysis of the ski industry in the European Alps (Abegg et al., 2007) and specifically chosen to facilitate comparison.

The lapse rate adjusted temperature data was then input into the ski operations model developed by Scott et al., (2003). 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 many previous climate change and ski tourism vulnerability studies has been the complete absence of snowmaking, likely causing over-estimations of the potential future impacts. The approach developed by Scott et al., (2003) incorporates snowmaking by including certain technical capacities (i.e. minimum temperature at which snow can be made economically and daily snowmaking capacity) and stakeholder derived decision making rules (i.e. start/end dates, target snow pack depth to maintain). The snowmaking capabilities modeled represent those of an advanced snowmaking system and assume 100% coverage of skiable terrain. The assumption of 100% coverage and advanced snowmaking capability is reasonable for most of the 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 (NSAA, 2007). Because of this, and because it is possible for all resorts to develop larger snowmaking capabilities (i.e. adaptive capacity), all ski areas were modeled using the same snowmaking capacity (both 100% terrain coverage and 10 cm snow depth over all skiable terrain per day).

Using the modeled natural snow depth and snowmaking enhanced snow depth, ski area operation indicators including ski season length, snowmaking requirements and probability of being operational during important holiday periods, were examined for three future time periods (i.e. 2010-39, 2040-69, and 2070-99) (see Appendix 1 for full results tables by state). For concise presentation, results from the three GCMs (GFDL, HadCM3, PCM) were averaged for both the lower (B1) and higher emission (A1fi) scenarios for each of the three future time periods (2010-39, 2040-69, 2070-99).

3.3 Results

3.3.1 Season Length

Projected ski season lengths show decreases at all 103 ski areas under all climate change scenarios for all future time periods. The extent to which season length is shortened is more severe for some ski areas than others. Results from the ski areas located at higher elevations (i.e. many ski areas in New Hampshire and Vermont) show longer season lengths in the baseline and under all climate change scenarios for all future time periods than those resorts located at lower elevations (i.e. many ski areas in Connecticut, Massachusetts, Maine and southern New York).

Of particular note, are the projections for ski areas in Connecticut where even under a low emission scenario (B1) for the 2010-39 time period 100% of ski areas in the region were projected to experience at least a 30% reduction in season length. Six percent of ski areas in New York were projected to experience between a 25 and 49% reduction in season length. Under the high emissions scenario (A1fi) for this time period (2010-39), 17% of ski areas in Massachusetts were expected to see between a 25 and 49% reduction. Even under this high emissions scenario the majority of ski areas in Maine, New Hampshire, Massachusetts, New York and Vermont were only projected to experience between 10 and 20% reductions in season length. Ski areas in Vermont were projected to maintain the longest season lengths with 89% of ski areas projected to lose less than 10% of their season length (Table 8).

Table 8: Projected change in ski season length for 2010-39 time period

	B1 Low Emissions						**A1 High Emissions**					
	> - 50%		**- 25 to - 49%**		**< - 24%**		**> - 50%**		**- 25 to - 49%**		**< - 24%**	
	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas
CN	0	0	5	100	0	0	0	0	5	100	0	0
MN	0	0	0	0	14	100	0	0	0	0	14	100
MA	0	0	0	0	12	100	0	0	2	17	10	83
NH	0	0	0	0	18	100	0	0	0	0	18	100
NY	0	0	2	6	34	94	0	0	2	6	34	94
VT	0	0	0	0	18	100	0	0	0	0	18	100

Note: Connecticut n=5, Maine n=14, Massachusetts n=12, New Hampshire n=18, New York n=36, Vermont n=18

Under a low emission scenario (B1) for the 2040-69 time period 42% of ski areas in Massachusetts are expected to experience reductions in season length of between 30 and 43% and 14% of ski areas in New York are projected to lose up to 30% of season length. In contrast, 56% of the ski areas in New Hampshire and 100% of ski areas in Vermont were projected to experience ski season length losses of less than 15%. Under the high emission scenario (A1fi) all of ski areas in Connecticut are projected to experience between a 50 and 60% decrease in season length (Table 9).

Table 9: Projected change in ski season length for 2040-69 time period

	B1 Low Emissions						**A1 High Emissions**					
	> - 50%		**- 25 to - 49%**		**< - 24%**		**> - 50%**		**- 25 to - 49%**		**< - 24%**	
	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas
CN	0	0	5	100	0	0	5	100	0	0	0	0
MN	0	0	0	0	14	100	0	0	0	0	14	100
MA	0	0	5	42	7	58	0	0	0	0	12	100
NH	0	0	0	0	18	100	0	0	0	0	18	100
NY	0	0	5	14	31	86	0	0	0	0	36	100
VT	0	0	0	0	18	100	0	0	0	0	18	100

Note: Connecticut n=5, Maine n=14, Massachusetts n=12, New Hampshire n=18, New York n=36, Vermont n=18

For the 2070-99 time period, ski areas in Connecticut were projected to lose an average of 55% of their season under the low emissions scenario (B1). During this time period and emission scenario half of the 14 ski areas in Maine, all of the ski areas in Massachusetts, half of the 18 ski areas in New Hampshire, and 23 of 36 the ski areas in New York are projected to experience season length reductions of between 25 and 49%. Under the high emissions scenario (A1fi) four of the five ski areas in Connecticut are projected to experience a decrease in season length of more than 75%. For this scenario, six of 14 ski areas in Maine, five of 12 ski areas in Massachusetts and 22 of 36 ski areas in New York are projected to see season length decreases of greater than 50%. Once again ski areas in Vermont are the least vulnerable with projected season length reductions of between 24 and 38% for all ski areas under this scenario (see Table 10).

Table 10: Projected change in ski season length for 2070-99 time period

	B1 Low Emissions						**A1 High Emissions**					
	> - 50%		**- 25 to - 49%**		**< - 24%**		**> - 50%**		**- 25 to - 49%**		**< - 24%**	
	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski aeas	# ski areas	% ski areas	# ski areas	% ski areas
CN	5	100	0	0	0	0	5	100	0	0	0	0
ME	0	0	7	50	7	50	6	43	5	36	3	21
MA	0	0	12	100	0	0	5	42	7	58	0	0
NH	0	0	9	50	9	50	1	6	15	83	2	11
NY	0	0	23	64	13	36	22	61	14	39	0	0
VT	0	0	1	6	17	94	0	0	18	100	0	0

Note: Connecticut n=5, Maine n=14, Massachusetts n=12, New Hampshire n=18, New York n=36, Vermont n=18

3.3.2 Snowmaking Requirements

In order to limit ski season length loss, snowmaking requirements were projected to increase for all of the 103 ski areas in the U.S. Northeast. Under the low emissions scenario (B1) for the 2010-39 time period three of 14 ski areas in Maine are projected to have increased snowmaking requirements of more than 50%. Snowmaking requirements for 18 of the 18 ski areas in New Hampshire, eight of the 36 ski areas in New York and 18 of the 18 ski areas in Vermont are expected to increase by between 25 and 49%. Under the high emissions scenario (A1fi) for this time period snowmaking requirements remain very similar to that projected in the low emissions scenario.

In the 2040-69 time period, three of 14 ski areas in Maine and three of 18 ski areas in New Hampshire are projected to increase snowmaking by more than 50% under the low emissions scenario (B1). In Vermont, eight of 18 ski areas are expected to experience increased snowmaking requirements of between 50 and 74% while five of 18 ski areas in Maine, three of 12 ski areas in Massachusetts, 15 of 18 ski areas in New Hampshire and 10 of 36 ski areas in New York will see increases between 25 and 49%. During the high emissions scenario (A1fi) for this time period seven of 18 ski areas in Maine, 13 of 14 in New Hampshire, four of 36 in New York and 18 of 18 ski areas in Vermont are projected to require increases in snowmaking requirements by more than 50%.

During the 2070-99 time period and under the low emissions scenario (B1) snowmaking requirements increase by more than 50% for four of 14 ski areas in Maine, nine of the18 ski areas in New Hampshire and 12 of the18 ski areas in Vermont. Seven of 14 ski areas in Maine and eight of 16 in New Hampshire are projected to increase snowmaking requirements by between 25 and 49%. Under the high emissions scenario (A1fi) 10 of 14 ski areas in Maine, 12 of 18 in New Hampshire, eight of the 36 ski areas bin New York and 18 of the 18 ski areas in Vermont are projected to increase snowmaking by over 50% (Table 11).

Snowmaking requirements for many lower lying ski areas in Connecticut and New York are expected to increase less dramatically than for those ski areas located at higher elevations in, for example, Vermont and New Hampshire. The reasons for this are twofold. Ski areas located at lower elevations are already producing more snow under current climate conditions; therefore the percent change in snowmaking does not increase as quickly as for those not currently producing this baseline amount of snow. Secondly, the ski-sim snow module used in this study restricts snowmaking to days when temperatures are at least -5°C (23°F), which is the temperature that current technology allows for efficient snowmaking (Scott et al. 2003). Ski areas located at lower elevations where higher temperature are more prevalent are projected to experience a higher proportion of days warmer than -5°C (23°F) in comparison to higher elevated ski areas and may therefore be restricted in their snowmaking efforts.

Table 11: Projected change in snowmaking requirements

	B1 Low Emissions						**A1 High Emissions**					
	> 50%		**-25 to 49%**		**< 24%**		**> 50%**		**25 to 49%**		**< 24%**	
						2010-39						
	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas	# ski areas	% ski areas
CT	0	0	0	0	5	100	0	0	0	0	0	0
ME	3	21	4	29	7	50	3	21	6	43	5	36
MA	0	0	0	0	12	100	0	0	0	0	12	100
NH	0	0	18	100	0	0	0	0	18	100	0	0
NY	0	0	8	22	28	78	0	0	7	19	29	81
VT	0	0	18	100	0	0	0	0	18	78	0	0
						2040-69						
CT	0	0	0	0	5	100	0	0	0	0	5	100
ME	3	21	5	36	6	43	7	50	7	50	0	0
MA	0	10	3	25	9	75	0	0	9	75	3	25
NH	3	17	15	83	0	0	13	72	5	28	0	0
NY	0	0	10	28	26	72	4	11	11	31	21	58
VT	8	44	10	56	0	0	18	100	0	0	0	0
						2070-99						
CT	0	0	0	0	5	100	0	0	0	0	5	100
ME	4	29	7	50	3	21	10	62	3	21	1	7
MA	0	0	3	25	9	75	0	0	4	33	8	67
NH	9	50	9	50	0	0	12	67	6	33	0	0
NY	4	11	6	17	26	72	8	22	5	14	23	64
VT	16	88	2	12	0	0	18	100	0	0	0	0

Note: Connecticut (CT) n=5, Maine (ME) n=14, Massachusetts (MA) n=12, New Hampshire (NH) n=18, New York (NY) n=36, Vermont (VT) n=18

3.3.3 Probability of Being Operational During Christmas-New Year Holiday

Two holiday periods are economically critical in this ski marketplace. In the US Northeast ski region, up to 20% of skier visits occur in the twelve-day holiday period between December 23rd and January 3rd (NSAA, 2005) and, as such, being operational during this time period is extremely important. However, because the Christmas/New Year holiday falls early in the snow season it is sometimes difficult for ski areas to be fully operational at this time. Another important holiday period is the week long March/school break (~10% visitation – NSAA, 2005), which generally falls near the end of the ski season sometimes making it challenging for ski areas to stay operational if very warm conditions occur. However, the majority of ski areas have, in recent years, been able to use snowmaking to maintain a sufficient base to remain open during this period. Because of this factor, the focus of this analysis is on the Christmas-New Year holiday period.

The probability that ski areas in the region will be fully operational for the duration of the 12-day Christmas-New Year holiday was examined for all of the 103 ski areas in US Northeast. Projections are fairly constant between time periods, with any significant impacts appearing by the end of the 2010-39 time period. In total, 94% of ski areas in Vermont and 50% of ski areas in Maine, and New Hampshire are projected to be operational during the Christmas-New Year period at last 75% of the time (i.e. 7.5 years out of 10) during the 2010-39 time period. Only 31% of ski areas in New York and none of the ski areas in Connecticut of Massachusetts are expected to be operational at least 75% of the time during this key holiday period. Under the high emissions scenario 50% of ski areas in Maine, 33% in New Hampshire, 17% in New York, 89% in Vermont, and 0% in Connecticut and Massachusetts are projected to maintain at least a 75% probability of being operational for the 2010-39 time period. Ski areas in Connecticut and Massachusetts are projected to have the most difficulty staying operational during the Christmas-New Year holiday, followed by New York and Maine. Ski areas in New Hampshire and in particular those located in Vermont are projected to be the least susceptible to closures during this holiday period (Table 12).

Table 12: Projection of ski areas with at least 75% probability of being operational during the Christmas-New Year holiday

		2010-39		**2040-69**		**2070-99**	
	Total Ski Areas	**B1** n(%)	**A1fi** n(%)	**B1** n(%)	**A1fi** n(%)	**B1** n(%)	**A1fi** n(%)
Connecticut	5	0(0)	0(0)	0(0)	0(0)	0(0)	(0)0
Maine	14	7 (50)	7(50)	7 (50)	7(50)	7(50)	3(50)
Massachusetts	12	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
New Hampshire	18	9(50)	6(33)	7(39)	3(17)	6(33)	0(0)
New York	36	11(31)	6(17)	6(17)	2(3)	5(14)	0(0)
Vermont	18	17(94)	16(89)	16(89)	15 (83)	16(89)	4(22)
Northeast Region	103	44(43)	35(34)	36(35)	27(26)	34(33)	7(7)

Note: Connecticut n=5, Maine n=14, Massachusetts n=12, New Hampshire n=18, New York n=36, Vermont n=18

3.4 Discussion

3.4.1 Climate-Induced Contraction of the US Northeast Ski Area Marketplace

The combination of shortened ski season length, increased snowmaking requirements and decreased probability of being operational during the economically important Christmas-New Year holiday period is likely to cause revenue reductions and increased operating costs for ski areas across the US Northeast (Box 1).

Box 1: Economic impact of climate change on ski area supply

If, under a high emissions scenario for the 2049-60 time period, ski areas in the US Northeast...

- lost the Christmas-New Year holiday[(a)],
  - revenue reduction = US$183,600,000
- lost shoulder seasons (open – Dec 21 & April – close[)(b)]; and
  - revenue reduction = US$ 137,700,000
- experienced a 42% increase in snowmaking requirements [(c)]
  - expense increase = US$ 1,169,000

The total impact could be = $322,468,000 per season

(a) 20% visitation during this time period X $68 revenue per skier visit X average of 13,500,000 visits (NSAA, 2007)

(b) 15% visitation during these time periods X $68 revenue per skier visit X average of 13,500,000 visits (NSAA, 2007)

(c) Average regional increase in snowmaking requirements (Chapter 3) X seasonal cost of snowmaking (NSAA, 2007).

Note: Values are in 2007 US dollars – assessment of future financial impact will require consideration of inflation

Climate change is likely to play a significant role in determining the economic sustainability of ski businesses in the region, with the likely outcome being a continuation of the historic contraction of the sector favoring those who are able to afford the increased costs of adaptation (i.e. snowmaking). Broad indicators can be used to explore the future economic sustainability of ski area operations. A commonly used benchmark is the '100-day rule' (König & Abegg, 1997; Bürki, 2002; Erickson, 2005), which argues that in order for a ski area to remain profitable, it has to maintain annual season lengths of at least 100 days.

In the US Northeast region only 57 and 56 of the 103 ski areas are projected to be able to maintain 100-day season lengths under the low (B1) and high (A1fi) emissions scenario in the 2010-39 time period. These figures drop to 56 and 41 in the 2040-69 time period and 46 and 30 in the 2070-99 time period respectively. At the state level, none of the ski areas in Connecticut and Massachusetts are projected to be able to maintain season lengths of 100 days in the 2010-39 time period under either the low or high emissions scenario. In the 2040-69 time period, under low and high emission scenarios respectively, only 57% and 50% of ski areas in Maine and New Hampshire and 100% and 22% of ski areas in New York have season lengths of more than 100 days. In the 2070-99 time period, 67% and 22% of ski areas in New Hampshire, and 25% and 6% of ski areas in New York have season lengths of greater than 100 days under the low and high emissions scenario respectively. Ski areas in Vermont are the least vulnerable to climate change, with 100% (B1) and 94% (A1fi) of ski areas maintaining ski season lengths of greater than 100 days into the 2070-99 time period (Table 13).

Table 13: Projected ski areas with ski season lengths of 100+ days

		2010-39		**2040-69**		**2070-99**	
	Total Ski Areas	**B1**	**A1fi**	**B1**	**A1fi**	**B1**	**A1fi**
Connecticut	5	0	0	0	0	0	0
Maine	14	8	8	8	7	7	7
Massachusetts	12	1	0	0	0	0	0
New Hampshire	18	17	17	17	9	12	6
New York	36	13	13	13	8	9	2
Vermont	18	18	18	18	17	18	17
Northeast Region	103	57	56	56	41	46	30

As mentioned above, Scott et al. (2008) outlined the importance of considering not only the length of a ski season, but also what part of the season days are lost due to closures (i.e. highly valuable holiday periods vs. parts of the season with low visitation). In this study, the potential contraction of the US Northeast ski area marketplace (103 ski areas) is examined using a combination of the 100-day season length threshold, and less than 75% probability that a ski area would not operate for the entire Christmas-New Year's holiday period. When considering the two economic indicators examined in this study in combination ('100 day rule', see table 13, and probability of being operational during the Christmas-New Year period, see table 12), a significant contraction of ski areas is revealed (Figure 6).

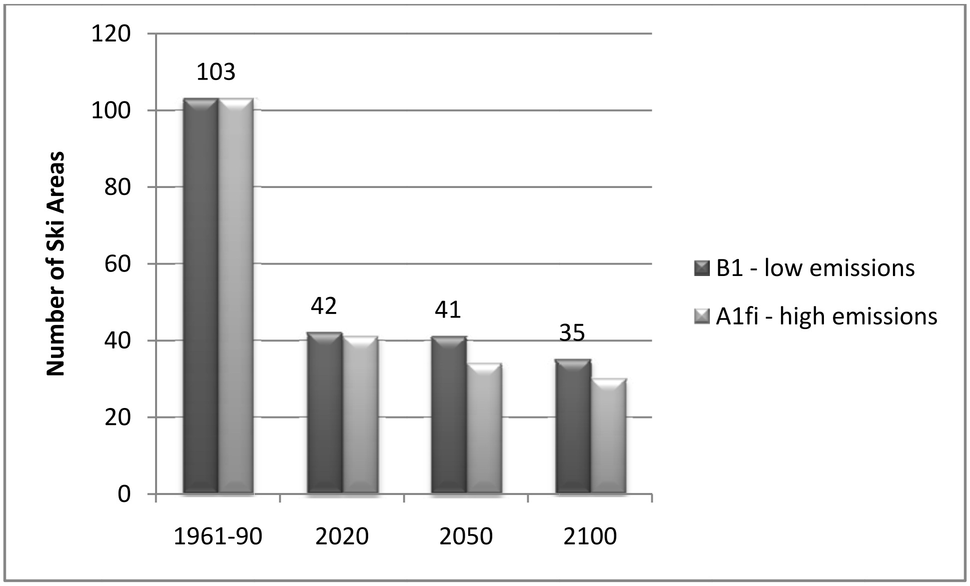


Figure 6: Regional contraction of ski areas based on economic sustainability dimensions

Regional distribution of the least and most vulnerable ski areas is clearly delineated from north to south (Figures 7 and 8 – also see Appendix 2). Ski areas in the southern portion of the US Northeast region, including Connecticut, Massachusetts and southern New York, are projected to experience climatic challenges making it very difficult to maintain 100 day ski seasons as early as within the next two to three decades. Conversely, ski areas located in more northern latitudes and generally higher elevation, including many operations in Vermont, New Hampshire, Maine and northern New York, are expected to be significantly more resilient to projected climatic change and in some cases will maintain at least 100 day seasons until the end of the twenty-first century even under high emissions scenarios.

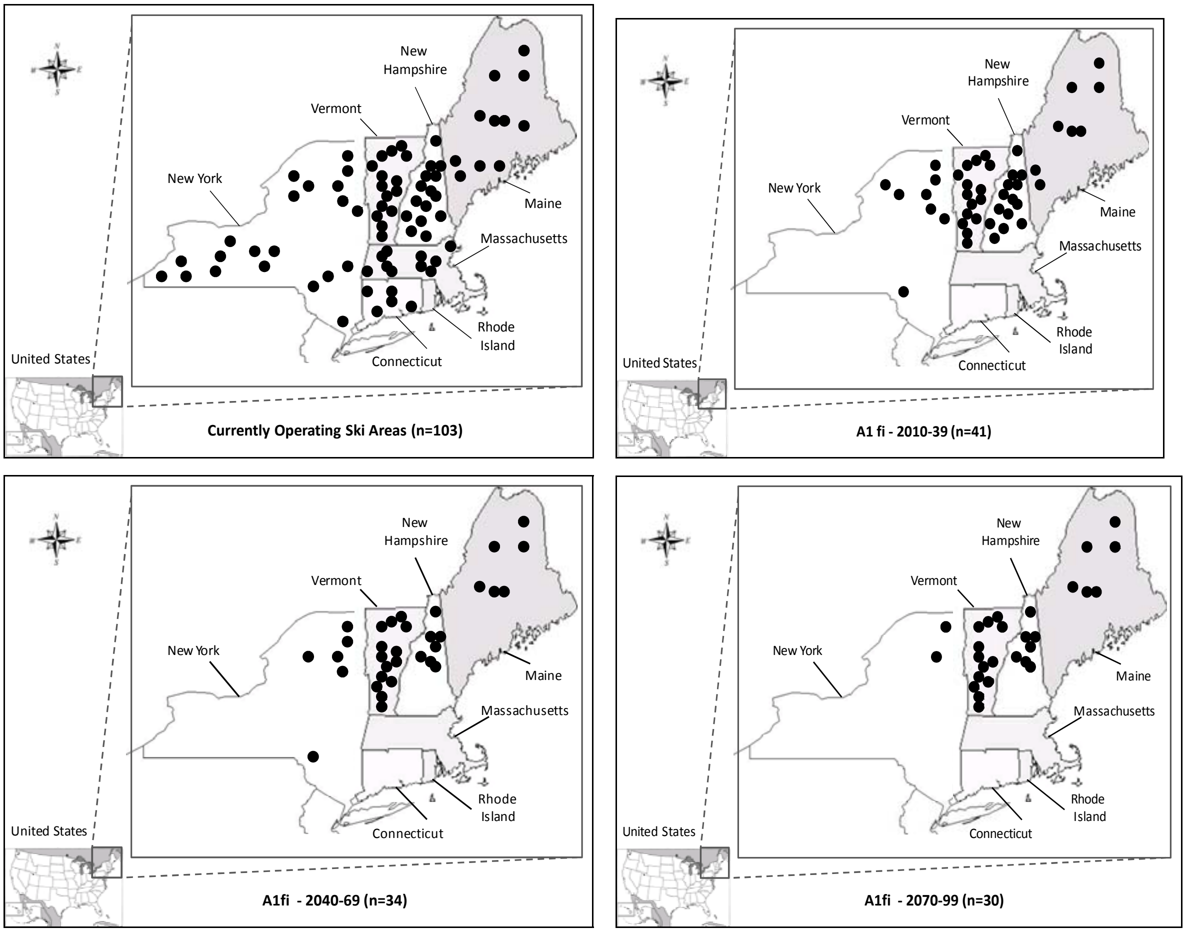


Figure 7: Contraction of the US Northeast ski areas marketplace under the A1fi - high emissions scenario

	Economically Sustainable Ski Areas (A1fi) *(100-day season and >75% probability of being operational during holiday periods)*
2010-39 (n=41)	NY – (12) whiteface(13) gore (14) oak (15) mccauley(16) royal (17) west, willard (18) cortina (21) bobcat; VT – (22) jay peak (23) smugglers notch (24) bolton , stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH –(37) balsams, loon (38) cannon (39) bretton (40) wildcat (43) watterville (47) sunapee ; ME – (52) saddleback, sugarloaf, sunday river (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson
2040-69 (n=34)	NY – (12) whiteface (13) gore (14) oak (15) mccauley; VT – (22) jay peak (23) smugglers notch (24) bolton , stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat, ((43) watterville ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson
2070-99 (n=30)	NY – (12) whiteface (14) oak; VT – (22) jay peak (23) smugglers notch (24) bolton, stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat (43) watterville; ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw

Note: numbers in brackets correspond to ski area location outlined in figure 2

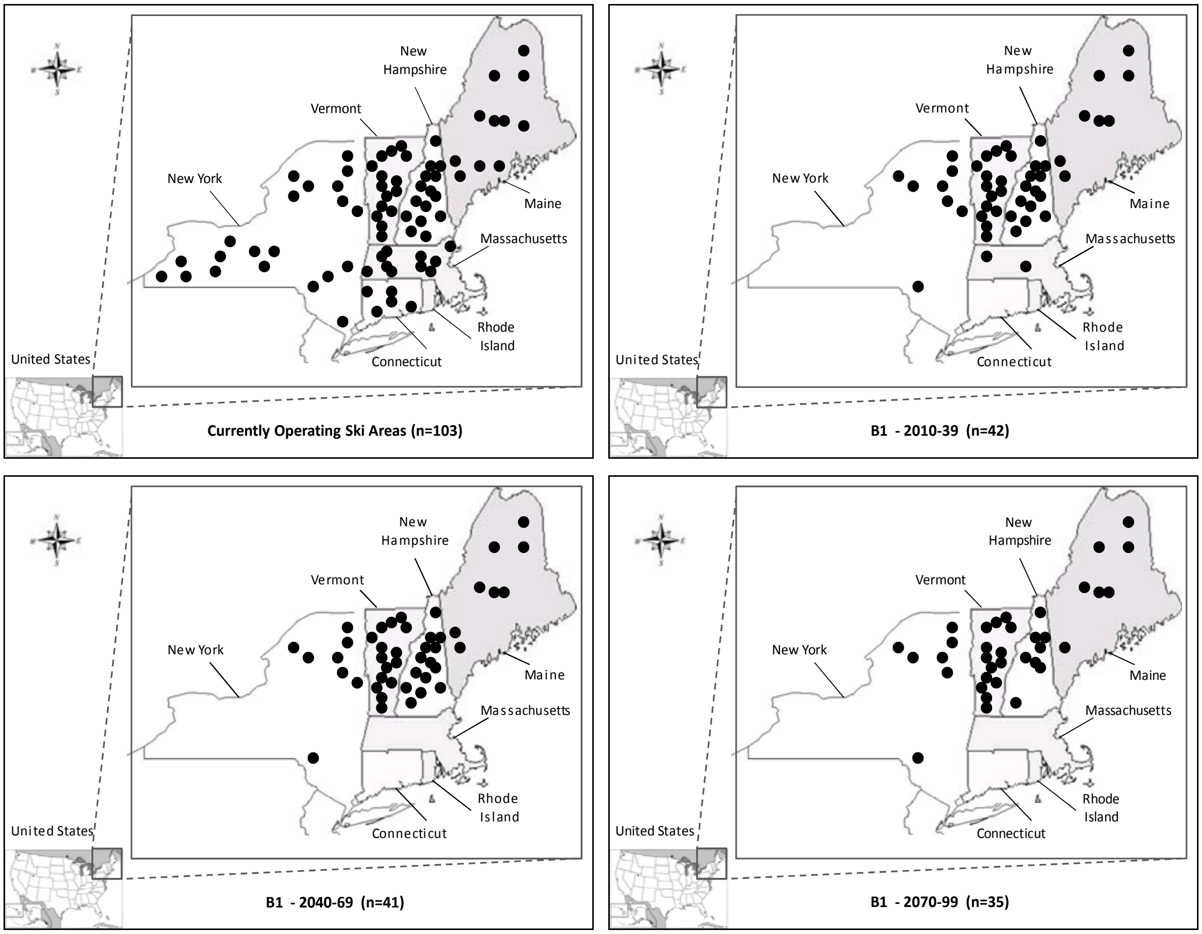


Figure 8: Contraction of the US Northeast ski area marketplace under the B1 - low emissions scenario

	Economically Sustainable Ski Areas (B1) *(100-day season and >75% probability of being operational during holiday periods)*
2010-39 (n=42)	NY – (7) dryhill (12) whiteface(13) gore (14) oak (15) mccauley(16) royal (17) west, willard (18) cortina (21) bobcat; VT – (22) jay peak (23) smugglers notch (24) bolton , stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH –(37) balsams, loon (38) cannon (39) bretton (40) wildcat (43) watterville (47) sunapee ; ME – (52) saddleback, sugarloaf, sunday river (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson
2040-69 (n=41)	NY – (12) whiteface (13) gore (14) oak (15) mccauley(17) west(21) bobcat (18) cortina; VT – (22) jay peak (23) smugglers notch (24) bolton, stowe (25) cochran (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat, (43) (47) sunapee, watterville (48) ragged (49) gunstock ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson
2070-99 (n=35)	NY – (12) whiteface (13) gore (14) oak (15) mccauley(16) royal(21) bobcat; VT – (22) jay peak (23) smugglers notch (24) bolton, stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke(36) suicide six; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat (43) watterville; ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw

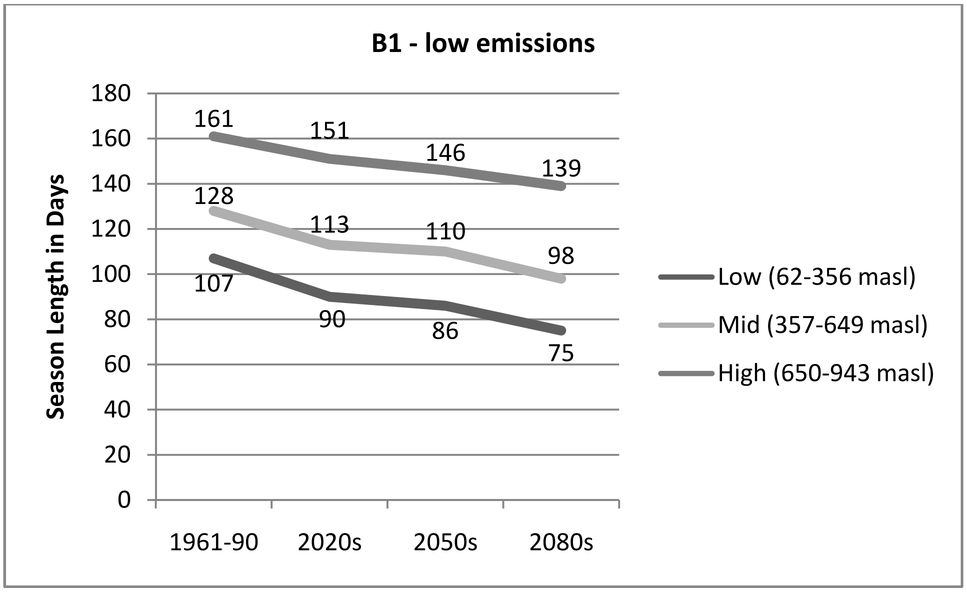
When specifically examining elevation in comparison to the differential vulnerability of ski areas in the US Northeast, it is evident that ski areas at higher elevations are significantly advantaged in terms of season length. The mid-range elevation (i.e. summit -base/2) of ski areas in the region range from 62 to 943 masl and have an average elevation of 705 masl. Ski areas were divided into three categories based on an equal division of elevation range (low = 62-356 masl, mid = 356-649 masl, and high = 649-943 masl). Using this categorization, there are 58 low resorts, 22 medium resorts and 23 high resorts currently operating in the US Northeast (Table 14).

Table 14: Elevation categories of ski area (by state)

State	Elevation Category
Connecticut	5 low
Massachusetts	11 low, 1 mid
Maine	11 low, 3 mid
New Hampshire	4 low, 9 mid, 5 high
New York	25 low, 7 mid 4 high
Vermont	2 low, 2 mid, 14 high
Northeast Region	58 low, 22 mid, 23 high

Note: low (62-356 masl), medium (356-649 masl), high (649-943 masl)

None of the ski areas in the 'low' elevation category (62-356 masl) in the US Northeast are projected to maintain 100-day seasons in either of the low (B1) or high (A1fi) emissions scenario in the 2010-49 time period. This is particularly of concern for ski areas in Connecticut and Massachusetts where all but one of the ski areas are situated at low elevation. This, in combination with the southern location of these states, makes ski areas in these areas the most vulnerable in the Northeast region to future climate change. Ski areas in Vermont are projected to be the least vulnerable to climate change as they are situated at a more ideal northern location and many of the states ski areas are located at higher elevation. Maine, New Hampshire and New York have a range of ski areas that are situated at varying elevations, meaning some ski areas are at significantly more risk than others depending on their exact locations (Figure 9).



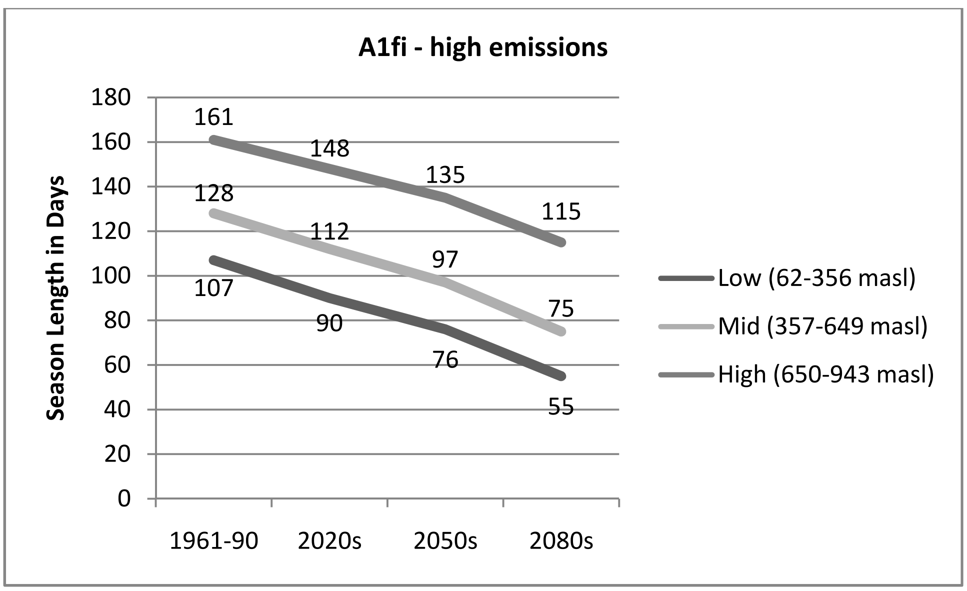


Figure 9: Differential vulnerability of ski areas based on elevation

3.4.2 Adaptation to Projected Supply-Side Impacts

The climate-induced evolution in the Northeast ski tourism marketplace will mean that all communities with sizable ski tourism will need to prepare to adapt to climate change, but for very different reasons. Contraction of ski area supply in the US Northeast region could impact operators and communities in very different and profound ways, likely advantaging the areas where ski areas remain operational. Assuming skier demand stays relatively stable, the 30 to 42 ski areas, that in this study are projected to remain in operation beyond the end of the 21st century, could be in a position to take advantage of a changed business environment whereby they gain market share due to lost competition. Although these ski areas and associated communities are likely to benefit from increased or stable tourism revenue, they will need to prepare for increasing development pressures (e.g. water use for snowmaking, real estate development, slope expansion, congestion) associated with the concentration of ski tourism in fewer areas. Increasingly crowded slopes, ski chalets and lift lines are likely to result. Transportation infrastructure, including ski area parking lots and roadways may require expansion with increased visitation and congestion. Community-based impacts could include increasing real-estate values, such that local residents may no longer be able to afford to live nearby, as well as increased pressure on local services and environmental resources.

In turn, the communities that lose ski tourism operations will need to develop economic diversification strategies, due to lost winter tourism revenues and related jobs, and could also see increased pressure on social services and unemployment as well as a drop in real-estate value (see Hamilton et al., 2007; Scott et al., 2008). These more vulnerable ski areas will, at varying points, need to determine if they should invest heavily in adaptations that will aid in continuation of a snow-based business at least in the short to medium term (i.e. high efficiency snowmaking, renewable energy production), if they should invest in adapting and evolving into a multi-season destination (i.e. four-season resort, spa, conference centre), or if they ultimately need to terminate their business altogether (see Figure 4, p. 48 – operator decision making flowchart). If the latter is decided, as projected for many ski areas in the southern portion of the region, it will undoubtedly impact the livelihoods of thousands of individuals who will have to invest in alternative economies.

Scott & McBoyle (2007) summarized a range of adaptation options available to ski areas which could help reduce their vulnerability to climate change, including both technological factors (i.e. increased or improved snowmaking systems, slope development and operational practices, clouds seeding) and altered business practices (i.e. ski conglomerates, revenue diversification, marketing, indoor ski areas). With the exception of current snowmaking capabilities (i.e. threshold of -5°C) the modeled contraction of ski areas supply does not include the alternative adaptation options that are available to ski areas. This is because future ski area adaptation is likely to be individualistic in nature due to the complexity of different factors requiring careful considering by each ski area manager (Scott & McBoyle, 2007 – Figure 1, p. 11). Some climate change adaptation strategies will be more successful in particular regions than others. For example, one of the most commonly cited adaptation strategies being considered by ski areas in the European Alps is moving ski areas to a higher elevation where snow cover is more reliable and ski seasons are lengthened (König & Abegg, 1997; Elsasser & Bürki, 2002; Breiling & Charamza, 1999; Wolfsegger et al., 2008). This adaptation is not an option in the US Northeast region where ski areas are generally already located at any viable peak elevation. Feasible adaptation strategies for the US Northeast region are likely to include increased snowmaking, investment in alternative energy production and innovative business strategies.

The success of altered business practices used to adapt to marginal snow conditions in the US Northeast can be evaluated by comparing modeled season length projections from this study (which do not include business-decisions) with the results of an analogue analysis, which is based on actual events and is therefore able to capture business-management adaptations (i.e. opening under even very marginal conditions because of staffing inflexibility and to provide some level of skiing, perhaps only one or two runs, to guests staying in resort accommodations) (Dawson et al., 2009).The regionally averaged 1961-90 baseline modeled ski season in this study was 132 days, which compares well to the baseline of 133 days reported by Dawson et al., (2009). Ski seasons were projected in this study to decline to 116 days in the mid-range emissions scenario for the 2040-69 time period, which is a greater reduction than observed in the 2040-69 mid-range analogue (1998-99) of 128 days. For the high emissions scenario in the 2040-69 time period, the ski season length was projected to decline to 108 days under a high emission scenario (A1fi), which again was more than observed in the 2040-69 high emissions analogue (2001-02) where the season was 118 days. In the analogue analysis, conducted by Dawson et al., (2009), the US Northeast ski area marketplace experienced significant economic challenges due to shortened season lengths, increased cost of snowmaking and a net reduction in operating profit, but were still able to remain operational due to a variety of successful business adaptations (i.e. increased retail opportunities, increased marketing budget and decreased expenses per skier visit) (NSAA, 2001, 2002).

Climate change adaptation strategies for the ski sector have largely been focused on ski area supply with limited attention given to potential adaptative response of participants to projected impacts. Skiers can easily adapt their behaviour to climate variability by altering the destination or timing of participation or they may choose not to participate at all. König (1998) conducted a survey examining skier response to marginal future snow conditions at three Australian ski areas finding that 25% would continue to ski with no change, 31% would ski less often, six percent would quit skiing altogether and 38% would ski in alternative destinations (i.e. New Zealand or Canada). No known attempt has been made to assess the implications of climate-induced demand change on the economic sustainability of ski area operations or to outline how ski areas might adapt to significant changes in the skier market (Scott & McBoyle, 2007). For example, an individuals' willingness to travel longer distances to operating ski areas in North America is not well understood and is likely to significantly impact demand patterns for ski area operations. A survey of 540 skiers in Austria by Unbehaun et al., (2008) examined acceptable travel distance to a ski area for the purpose of a ski holiday (i.e. vs. a day-trip). Eight percent indicated a preference of 0-100 km, six percent preferred 101-250km, 58% felt that 251-500 km was acceptable and 35% would travel more than 500 km. Because the geography of Europe differs so drastically from North America these figures do not translate, however the research clearly identifies 500km as a threshold for the majority of skiers in Austria.

Due to the projected contraction of ski area supply in the US Northeast region in this study, individuals living in New York, NY would have to travel an additional 3 hours to get to an operating ski area under the high emission scenario (A1fi) for mid-century (2040-69). Individuals living in other major population centers such Boston, MA and Buffalo, NY will be required to travel between 2 and 5 additional hours respectively to participate at an operational ski area in the US Northeast region in comparison to available options today. Individuals living in the Canadian city of Montreal will not see any increase in travel distance in the 2040-69 time period as ski areas in the US Northeast that are in close proximity to the city are projected to remain operational at least until the end of the 21st century (Table 15). However, the extent to which individuals from this centre continue to ski in the US Northeast region is uncertain considering popular ski areas on the Canadian side of the border are also likely to be in operation late into the 21st century (see Scott et al., 2006b).

Table 15: Distance between operating ski areas and large population centres

Starting Location	Population (2007)	Today	2040-69 (A1fi high emissions)	Change
New York, NY	8,274,527	82km (51 mi) / 1hr 15 min (Mt. Peter, NY, Stirling Forest, NY)	404km (251 mi) / 4hrs 15 min (Mt. Snow, VT)[1]	+ 3 hrs
Montreal	1,620,693	196km (122 mi) / 2 hrs 31 min (Whiteface, NY, Bolton, VT)	196km (122 mi) / 2 hrs 31 min (Whiteface, NY, Bolton, VT)	N/A
Boston , MA	599,351	79km (48mi) / 1hr 1min (Nashoba, MA, Bousquet, MA)	246km (153m i) / 3 hrs 5 min (Mt Snow, VT)	+2hr 4min
Buffalo, NY	272,632	153km (95mi) / 1 hr 37 min (Peek n' Peak, NY Cockainge, NY, Holiday Valley, NY, Holimount, NY)	544 km (338 i) / 6 hrs 48 ins (Mccauley, NY, Bobcat, NY)[2] (Whiteface, NY)	+5hr 21min

[1] According to modeled projections Bobcat, NY would be closest; however it is reportedly closed for 2008/09

1 According to modeled projections McCauley, NY would be closest; however it is reportedly closed for 2008/09

The irony in the projected contraction of ski area supply causing increased travel distances for skiers is the resulting increase in transportation emissions which contributes further to climate change. Assessing the possible increase in travel emissions combined with an increase in emissions related to changing snowmaking requirements could be a fruitful exercise for future research. The GHG emissions associated with increasing snowmaking efforts at more vulnerable resorts could very well be less than if skiers traveled significant distances to participate at ski areas located at more snow rich areas. Another concern associated with increased travel distances between major urban centers and viable ski areas is a possible overall loss of skier participation. It is unclear how the future demographic of skiers will develop if existing skiers are not willing to travel longer distances to ski or perhaps more importantly if new skiers are not exposed to a skiing culture. Many smaller ski areas currently located in the highly vulnerable states Connecticut and Massachusetts act as 'nursery hills' to the larger ski resorts located further north. Currently, individuals from Boston and New York City are exposed to skiing and learn to ski at these local resorts. If a skiing culture does not exist within a 500km radius of these major centers it is possible that fewer individuals will take up the activity. This is evident through a simple spatial analogue of skier participants. According to the NSAA (2006b) the total percentage of skiers residing in popular and mountainous ski regions is 64% versus participants from more southern US regions with fewer skiing opportunities which contained just 31.3% of total skiing participants. When examining which US states create the most skiers it is clear that mountainous regions with preexisting ski resorts consistently produce more skiers than lower elevated states with less developed skiing cultures. For example, 11% of skiers during the 2006 season were from Colorado, a mountainous state known for good ski conditions, in comparison to states with less developed ski infrastructure like Tennessee, Alabama, or South Dakota which produced between 0% and 0.6% of total skiers (NSAA, 2006b).

3.5 Conclusion

Based on this analysis of 103 individual ski areas, it would appear that it is not the entire US Northeast ski industry that is at risk to climate change but rather individual ski businesses and communities that rely on ski tourism. Resorts that are least susceptible to a changing climate generally include those at higher elevation where temperatures are lower and those located at more northern latitudes. 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 the Northeast, it could advantage some of the ski operations that remain (e.g., Vermont and northern New Hampshire).

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. Ski areas across the US Northeast have many adaptation options that can help to decrease their individual vulnerability to future warming regimes. For example ski areas that will be most adaptable are those that take advantage of any opportunities that are presented and would likely involve diversifying their tourist products (i.e. all-season resorts/retail opportunity/non-snow activities/other snow activities), and business plans (i.e. partnering with large business conglomerates such as Intrawest Corporation so financial losses can be offset with gains in other locations, investing in renewable energy products, ensuring sustainable water availability).

Chapter 4: Climate Change and Behavioural Adaptation by Skiers and Snowboarders in the US Northeast

The ski tourism sector around the world has been identified as particularly vulnerable to future climate change. Supply-side studies project shortened ski season length and increased snowmaking requirements which may jeopardize revenues and increase operational costs. Demand-side impacts of climate change have received surprisingly little attention, considering tourists/recreationists can easily adapt their behaviour to climate variability by altering their destination (spatial substitution), frequency of participation (temporal substitution), and by changing leisure activities altogether (activity substitution). This study uses a survey (n=1,167) to examine demand-side adaptation of skiers in the US Northeast region to past marginal conditions and hypothetical future scenarios. Behavioural theory from the recreation and leisure literature is drawn upon to help understand projected changes in skier demand. The most common response to marginal snow conditions is travel to other ski areas with better snow conditions, followed by reduced frequency of participation. When examining the difference between how skiers have reacted to marginal snow conditions in the past and how they state they intend to react to similar or worse conditions in the future, there is little net change in behavioural responses. This suggests that under future climate change scenarios, demand is not likely to decrease proportionally to the projected decrease in supply. Thus a geographical market shift (i.e. greater demand/market share for ski areas that remain operational) is anticipated under future climate conditions.

Keywords: ski tourism, demand, climate change, US Northeast, theory of substituability

4.1 Introduction

Climate change has emerged as one of the most important challenges facing the tourism sector today (UNWTO-UNEP, 2003; Gössling & Hall, 2005; UNWTO-UNEP-WMO, 2008; World Travel & Tourism Council, 2009). Academic interest and media depictions of struggling tourism operations, particularly those involved with winter-based activities, has facilitated increased attention from the Intergovernmental Panel on Climate Change (IPCC, 2007), the United Nations Environment Program [UNEP], the United Nations World Tourism Organization [UNWTO], and the World Meteorological Organization (UNWTO-UNEP-WMO, 2008). As identified by Saarinen and Tervo (2006) climate was in the past considered "*an unchanging resource for the place-based tourism industry*" (p. 215). However current realities and projected change mean that climate can no longer be considered a constant, but rather a variable factor that requires increased analysis, understanding and planning.

Because of the high climate sensitivity of winter tourism, the ski industry has received significant attention within the international academic literature on climate change and tourism (see Abegg et al., 2007; Behringer et al.,2000; Breiling & Charamza, 1999; Casola et al., 2005; Dawson & Scott, 2007; Dawson et al., 2009; Elsasser & Messerli, 2001; Elsasser & Bürki, 2002; Fukushima, et al., 2002; Galloway, 1988; Hamilton et al., 2007; Hayhoe et al., 2004; Hennessy et al., 2003; König, 1998; König & Abegg, 1997; Lamothe & Périard Consultants, 1988; Lipski & McBoyle, 1991; Shaw & Loomis, 2008; Shih et al., 2009; McBoyle & Wall, 1987, 1992; Moen & Fredman, 2007; Scott et al., 2003, 2006, 2007, 2008; Steiger & Mayer, 2008; Unbehaun et al., 2008). Research attention has been mainly focused on examining the impact that climate change is expected to have on the supply-side of the ski sector (i.e. ski area operations). Ski area assessments have outlined several likely impacts of future climate change, including shortened season lengths and increased snowmaking requirements, which are likely to jeopardize revenue and increase operating expenditures.

Climate change assessments of the ski area marketplace in eastern North America, which have included the important adaptation of snowmaking, indicate that even under a high emission scenario, many ski areas are projected to remain operational into at least the mid twenty-first century (see Scott et al. 2003, 2006a, 2006b, 2007; Dawson & Scott, this manuscript – Chapter 3). Therefore, the entire ski area marketplace in eastern North America is not anticipated to be at risk to climate change, but rather at risk are the individual ski areas that are not be able to afford the cost of adapting to future change (i.e. mainly through the use of snowmaking or by diversifying business models). Communities that rely on these ski areas to drive winter tourism are also at considerable risk (Scott et al. 2008; Dawson & Scott, this manuscript-Chapter 2).

Now that an understanding has been established that there is likely to be a regional contraction of ski areas under future climate change, versus the complete elimination of the industry, further examination of the potential behavioural response of skiers to these projected supply-side changes becomes increasingly important. Tourists can easily adapt their behaviour in response to climate variability and poor snow conditions, especially in comparison to the difficulty and expense involved in structural and management-based adaptations currently being used or considered by ski areas (see Scott and McBoyle, 2007 for an overview of climate change adaptation strategies available to the ski sector).

For ski area managers, it is important to understand how activity participation decisions are made and also what constraints (i.e. costs, time) skiers have to negotiate in order to participate (Williams & Fidgeon, 2000) both now and under changed conditions in the future. In three existing studies that examine general constraints for ski tourists currently, the most commonly cited reasons for ceased participation in the activity, despite originally being involved, included having children who were too young to ski (Williams & Dossa, 1995), high costs involved in participation (Riddington et al., 2000), and lack of snow (Gilbert & Hudson, 2000). Climate variability leading to lack of snow has in the past caused varying degrees of difficulty for ski areas that are prone to changing snowfall patterns. Snowmaking has greatly decreased this risk allowing ski areas to produce snow during seasons or months with limited natural snowfall. However, climate change is likely to exacerbate this problem causing a decrease in natural snowfall and an increase in the cost to produce machine-made snow (see Scott et al., 2003, 2006, 2008).

Very few studies have considered how marginal snow conditions in the future may impact ski area demand. König (1998) utilized surveys to examine how skiers might respond to hypothetically poor snow conditions in the future, finding that 25% of skiers would continue skiing at the same place and frequency, 31% would ski less often, 38% would ski at another overseas location and 6% would quit skiing altogether. Similar surveys were conducted by Behringer et al., (2000) and Bürki (2002) to examine skier responses at resorts in Switzerland. Behringer et al., (2000) found that 30% of respondents would not change their skiing behaviour, 11% would ski at the same location but less often, 28% would ski at a more snow reliable resort at the same frequency, 21% would ski at a higher resort less often, and 4% would give up skiing altogether. Bürki (2002) found that the majority of skiers would ski at the same frequency (30% at the same resort, 28% at another snow reliable resort), 32% would ski less often, and four percent would stop skiing.

Two important limitations exist within these important initial attempts to examine climate change vulnerability of skier demand. None of the existing studies examine how individuals are already responding to marginal snow conditions at present or in the past in comparison to how they might respond in the future. Because of this omission, we do not have a reasonable understanding of expected behavioural change (i.e. net different) expected in the future under climatically changed conditions. More importantly, the climate change and tourism literature has yet to make the important theoretical link between the role of climate change and its importance in influencing individuals' decision making patterns. For example, Dawson (2007) and Scott et al., (2008) have suggested that the literature has not sufficiently utilized useful and available tourism and recreation theory/concepts that could greatly enhance our understanding of climate-induced behaviour change. Integrating the concepts of 'substitution' and 'specialization' could have important implications for enhanced understanding demand-side vulnerability in the ski tourism sector. For example, if ski area managers are to successfully reduce unwanted behaviour change (i.e. reduction in skiing participation) it is important to understand which individuals are most likely to change their participation patterns temporally (i.e. ski less often) or spatially (ski elsewhere), and why others might stop skiing entirely to participate in another activity altogether (i.e. do something else).

Iso-Ahola (1986) proposed the 'theory of recreation substitutability' suggesting that when participation in an originally intended activity is no longer possible (e.g. if a local ski area closes), it must be replaced by another activity. Literature examining substitution behaviour has mainly focused on commencing and maintaining involvement in particular activities, understanding drop-out rates and analyzing replacement rates/substitution tendencies (see Baumgartner & Heberlein, 1981; Boothby et al., 1981; Schreyer & Knoff, 1984; Donnelly et al., 1986; Iso-Ahola, 1986; Manfredo & Anderson, 1987; Jackson & Dunn, 1988; Bialeschki & Henderson, 1998; Backman & Crompton, 1990; Scott, 1991; Williams & Basford, 1992; Williams & Fidgeon, 2000; Gilbert & Hudson, 2000; Hall & Bo, 2000; Riddington et al., 2000). Since the theory of substitutability was conceived, conceptualizations and applications have forced its divergence into three main streams, including activity substitution (i.e. per the original definition), spatial substitution (participating in a different location than originally intended), and temporal substitution (participating at a different time or at a different frequency than originally intended) (see Hall & Bo, 2000; Gilbert & Hudson, 2000). Iso-Ahola's (1986) theory of recreation substitution is particularly relevant when examining the influence of climate change on recreational demand change within the ski tourism sector (Figure 10).

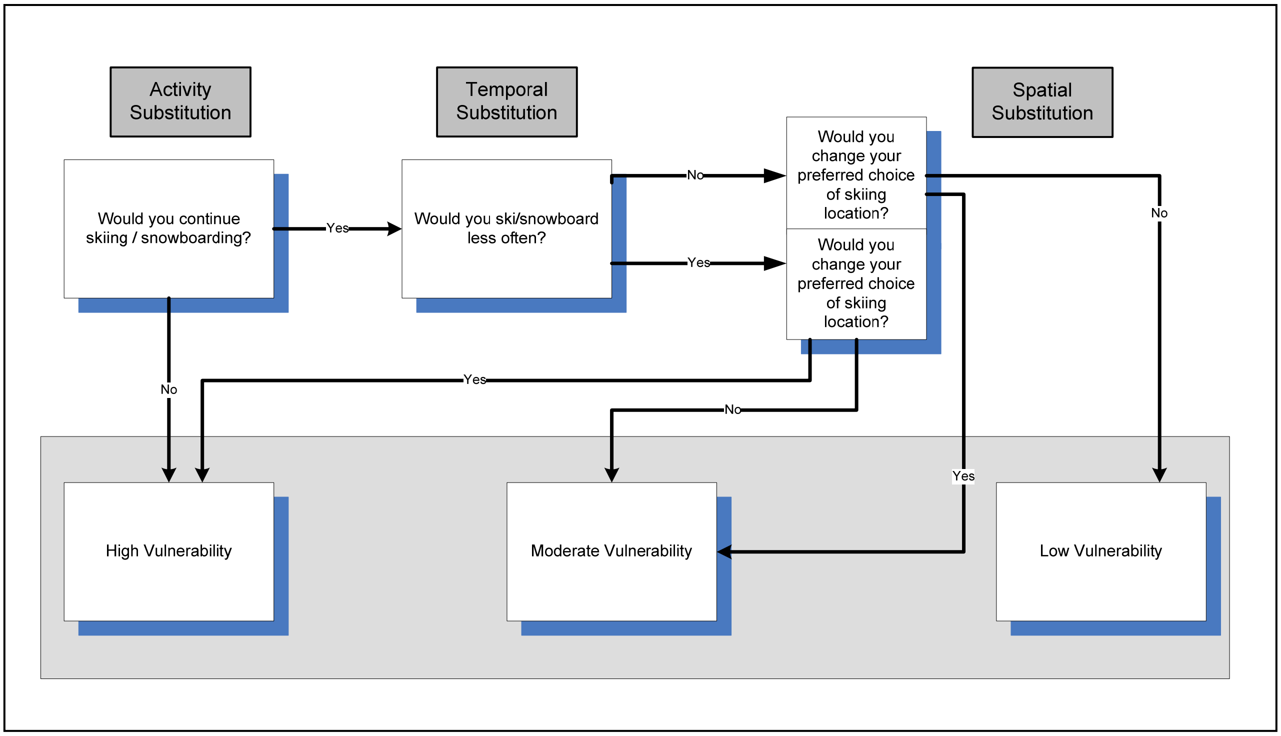


Figure10: Skier substitution flowchart (activity, temporal, spatial)

‘Specialization’, which refers to a continuum and progression of participation from the generalist to the ‘specialist’, is thought to play a significant role in substitution patterns (Bryan, 1977; Scott & Schafer, 2001). A specialist is someone who would limit their interests to a particular activity, while an unspecialized individual would exhibit more general recreation interests among a variety of activities. Individuals who are more specialized within a particular activity are generally more committed to regular participation, but often require increasingly particular settings in order to participate at desirable levels (Bryan, 1977; Scott & Schafer, 2001). Specialists tend to exhibit the most complex motivations and participation behaviours, as they have more information to draw upon when making decisions (Williams et al., 1990). Specialization levels can be measured by past experience and skill level, including the amount and type of events individuals have participated in (Ditton et al., 1992; Scott & Shafer, 2001). An individual’s past experience has been seen to serve as an effective indicator of on-site behaviours, motives for participation, perceptions of conflict, and support for managerial intervention (Schreyer & Knopf, 1984), which could be useful in understanding climate-induced behaviour patterns.

There is also some evidence from ski area managers in several North American and European locations that 'backyard' snow conditions at an individual's place of residence, as opposed to snow conditions at a particular ski area, also play an important role in influencing participation behaviour (Hamilton et al., 2007). However, limited attention has been paid to this phenomenon of 'backyard snow psychology' within the climate change and tourism literature. Additional research is needed to understand behavioural adaptation, including the role of 'backyard snow psychology' in substitution behaviour. Importantly, if people are willing to ski despite marginal snow conditions, the economic impact of climate change for ski areas will be less significant than if participants decide not to participate.

This study was designed to facilitate comparison with previous studies that have examined the impact of climate change on demand in the ski sector in Australia (König, 1998) and Switzerland (Behringer et al., 2000; Bürki, 2002). It also probes more deeply into the phenomenon of climate-induced behavioural adaptation, building on previous studies through three important dimensions. First, the study examines how people responded to marginal snow conditions in the past (specifically record warm winter of 2001-02 and the late ski season start of 2006-07), comparing them to how they intend to respond to similar, or worse, conditions in the future. This distinction elucidates the net difference between what people have done/are doing currently and what they intend to do in the future, therefore providing a more accurate measure of expected future demand change. Second, behavioural theory, drawn from social psychology and leisure studies literatures (specialization, past experience, constraints), was used to interpret and understand stated behavioural and differential responses among varying market segments. Thirdly, the study examines the role that 'backyard snow psychology' (i.e. the influence of snowfall at one's place of residence) plays on behavioural adaptation.

4.2 Methods

This study examines behavioural adaptation to marginal snow conditions and the potential impact of climate change on demand patterns for the US Northeast ski region. The Northeast ski region covers seven states, including New York, Vermont, New Hampshire, Maine, Massachusetts, Connecticut and Rhode Island. There are approximately 103 operating ski areas in the region with peak mid-range elevations of 1353 metres above sea level (masl) (NSAA, 2008; USGA, 2008). Some of the very first ski areas in the US were established in the Northeast region making the winter sports sector not only economically important to the area but also culturally significant. Skiers in the Northeast region, participate an average of 10 times per season, representing the highest participation rate in the country (National Sporting Goods Association, 2005). Of the five ski regions in the US, the Northeast consistently records the second highest total visitation rate (~13.5 million skier visits in 2007), just behind the Rocky Mountain region, which is host to large scale holiday resorts situated in highly desirable elevated mountainous terrain (~19 million skier visits in 2007) (NSAA, 2007). Winter sports are often highlighted in regional tourism marketing campaigns for the US Northeast, suggesting that this tourism market is an important one for the area. In fact, participation in snow-based activities in the Northeast region (excluding snowmobiling) is estimated to contribute $4.6 billion to the regional economy annually (Southwick Associates, 2006). The ski tourism sector in the state of Vermont alone contributes over US$1.5 billion to the annual state economy and creates over 13,000 jobs (VSAA, 2004).

The US is a vast country with diverse geography and topography meaning that regional climate conditions and future climate change projections vary significantly across the country (US National Assessment Team, 2001). Because of the diverse geography, ski season length and natural snow availability are different between each US region and also within the regions themselves, meaning that climate and future climate change scenarios are likely to impose disparate impacts on ski operators and skier demand patterns in different locations. In addition, Scott et al., (2007), Dawson and Scott (2007) and Dawson et al., (2009), have noted that size and elevation of a ski area play a role in dictating season length (i.e. higher elevation ski areas are typically able to maintain longer ski seasons) and operational decision-making processes (i.e. smaller resorts often have less investment in snowmaking equipment and management decisions differ from that of larger ski areas and ski conglomerates). Consequently, the study areas chosen for this survey were based on four criteria: 1) geographic location (north, middle, south of US Northeast region), 2) elevation of ski areas, 3) size of resort (smaller vs. larger resorts), and proximity to major urban markets (day trip and overnight trip from New York, Boston, Buffalo or Montreal).

For this study, six ski areas were chosen to represent the US Northeast region[3] (Figure 11). Operator participation in this study was 100% with six of the six identified ski areas choosing to allow the survey to be conducted on their premises. Of the six resorts, two were located in the north of the region, two in the middle and two in the south. Four were considered smaller ski areas and are located at lower elevations (i.e. < 457 m /1500 ft vertical drop), and two were considered larger resorts and are located at higher elevations (> 457 m/1500 ft vertical drop).

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[3] The names of the participating ski areas have been suppressed as per confidentially arrangements.

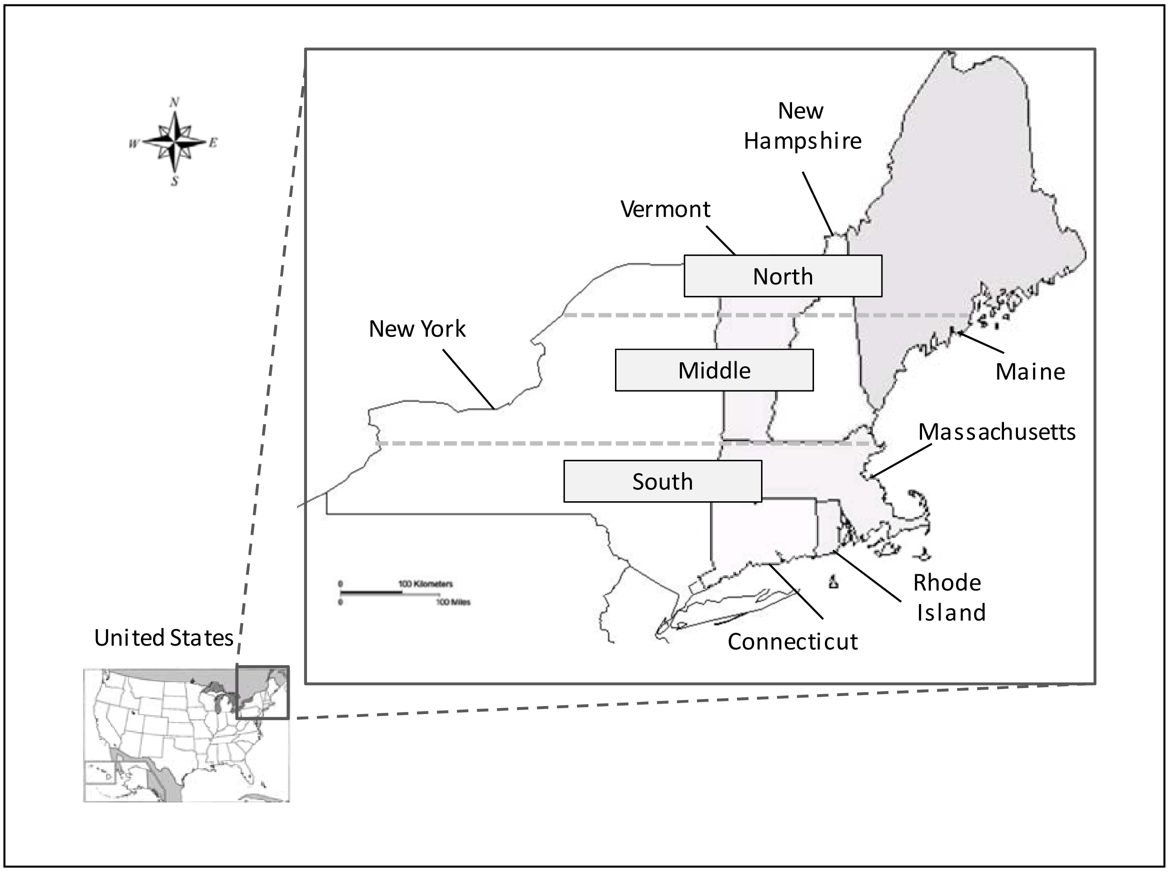


Figure 11: The US Northeast ski region and survey sample locations

A 32-item survey was developed to examine respondents' 1) participation habits, 2) behavioural response to past and future climatic conditions, and 3) demographic profile. At the core of the survey instrument (Appendix - 3) is a list of behavioural substitution options available to respondents when considering marginal snow conditions as the main influencing factor in participation. Respondents were asked if '*recent winters that had less than optimal snow conditions, because of warmer than usual temperatures or lower than average snowfall, adversely affected* [their] *ski/snowboard participation*'. The record warm winter of 2001-02 was given as an example of a marginal snow year. Because this season occurred several years ago, the more recent season of 2006-07, which had a very late start due to poor snow conditions was also provided. The list of substitution options was based on previous literature and allowed for multiple responses (i.e. *stop skiing for part of the season, stop skiing for a full season, travel within the US Northeast region, travel outside the US Northeast region, do something else, ski less often, ski more often, purchase less* *equipment/apparel*) (see König, 1998; Behringer et al., 2000). Following questions that examined behavioural response to past climatic conditions, participants were asked '*if the next 3 out of 5 seasons had very little snowfall (i.e. like the winter of 2001-02) how would this influence* [their] *decisions about if and where* [they] *would ski'*, therefore examining their expected reaction to future marginal conditions. The same list of possible responses was provided.

During a pre-test (n=15) of the instrument it was established that individuals engage in different substitution behaviours at different times. For example, it is possible for an individual to have 'skied less often' as a result of poor snow conditions in the past, as well as 'purchased less apparel related to skiing'. Consequently, the results of this study are not directly comparable to previous studies by König (1998) and Behringer et al., (2000) who did not allow for multiple responses; however, a general comparison can still be conducted.

In 2007, during the months of January and February, 1,309 skier/snowboarder surveys were handed out in ski chalets and cafeterias at the six selected ski areas. Eleven hundred and sixty seven surveys were returned, representing an 89% response rate. Of the 1,167 surveys returned, nine were considered invalid/incomplete and were not used in the analysis leaving a total of 1,158 analyzed responses. In total, 452 surveys (39%) were collected at northern ski areas, 479 at ski areas located in the middle of the region (41%), and 227 from ski areas in the south (20%). The distribution of respondents at large-high ski areas versus small-low ski areas was 692 (60%) and 466 (40%) respectively.

4.3 Results

The results of this study are divided into three sections including, demographic profile and trip characteristics of respondents, behavioural substitution tendencies, and factors influencing participation decision making.

4.3.1 Demographic Profile and Trip Characteristics

The profile of respondents in this study closely resembles the national skier/snowboarder profile developed by the National Ski Areas Association [NSAA] through their annual 'demographic study' (NSAA, 2006) and was considered to be a reasonably accurate representation of the US skier market (Table 1). The sample slightly over-represents skiers over snowboarders (84% and 16% respectfully) compared to the national average (63% and 37% respectfully). The sample also slightly over-represents self-rated intermediate skill level skiers (65% vs. 49%) and under-represents self-rated experts (26% vs. 41%). In this study, more respondents (47%) indicated having 20 or more years skiing of experience in comparison to the national average (38%). Although this may seem unusual considering fewer people in this study self-identified as having an 'expert' skill level, the number of years an individual participates in skiing does not always correlate with self-rated skill level. For example, many individuals cease skiing altogether, or ski less often during certain life-cycle stages including the child rearing years or career development stages (Gilbert & Hudson, 2000) and therefore may not develop what they consider to be an expert skill level despite having skied for a number of years.

The gender and age of respondents in this study very closely resemble national averages (59:41% vs. 60:40% male to female ratios and average age of 37 vs. 35 years). Slightly more people owned skiing or snowboarding equipment in this study (86%) compared to the national average (75%) and slightly more people held season passes (11% vs. 6%).

The trip characteristics of respondents also compare very closely with that of the NSAA (2006) national survey. The average length of a ski trip in this study was two days with a median of one day compared to a national average of one day and a median of two days. The number of days respondents in this study skied/snowboarded per year was on average 9 days with a median of 2. The NSAA national average number of days respondents skied/snowboarded per year was 13 with a median of 5. Finally, 19% of respondents in this study indicated they owned real-estate close to ski areas where they were skiing and an additional 15% rented property near ski areas, totaling 34% of respondents who either rent or own property for the purpose of participating in skiing or snowboarding activities (Table 16).

Table 16: Demographic and trip characteristics

Category	Subcategory	This Study (%)	National Average (%) NSAA (2006)
Activity	▪ Skiing ▪ Snowboarding	84 16	63 37
Gender	▪ Male ▪ Female	59 41	60 40
Age	▪ Mean	37	35
Education	▪ Elementary ▪ High school ▪ College/university ▪ Graduate/professional	1 12 55 32	n/a n/a n/a n/a
Real-estate property near ski area	▪ Own ▪ Rent	19 15	n/a n/a
Self-Rated Experience	▪ Beginner ▪ Intermediate ▪ Expert	9 65 26	10 49 41
Number of years skiing	▪ < 20years ▪ > 20 years	47 53	38 62
Equipment	▪ Own ▪ Rent	86 14	75 25
Season Pass	▪ This resort ▪ Other resort	23 11	29 6
Length of this trip	▪ Mean ▪ Median	2 days 1 day	1 day 2 days
Number of days skiing/snowboarding	▪ Mean ▪ Median	9 days 2 days	13 days 5 days

4.3.2 Behavioural Substitution

Similar to studies by König (1998) and Behringer et al., (2000), respondents were asked if marginal snow conditions would cause individuals to change their ski participation behaviour. König (1998) and Behringer et al., (2000) found that between 70 and 75% of respondents would alter their future participation habits (i.e. ski less, ski elsewhere, or quit skiing) if '*the next five winters would have very little natural snow*'. However, neither of these studies took into account the possibility that respondents were already engaging in similar substitution behaviour to marginal conditions in recent years, and as a result, the net change in behaviour may not be as great as indicated. For example, if 50% of respondents are already engaging in certain substitution behaviour (e.g. stop skiing for a season) and a similar proportion indicate that will engage in that behaviour in the future, then there would be no net change in behaviour. In other words, the demand response would largely be the same, only the conditions that drive them may be more frequent. Of course a higher frequency of marginal conditions may eventually lead to different, perhaps non-linear, behavioural responses; however, the thresholds for such conditions are likely very difficult to identify.

In this study, 79% of respondents indicated that during past seasons with marginal snow conditions (*similar to 2001-02 and the beginning of 2006-07*), they had stopped for an entire season and 79% stated they had skied more often as a result of shortened season lengths. Although these results may seem contradictory, it is likely that these behavioural responses occurred during different seasons. A limitation to questions requiring recall of past behaviour is that, despite being asked specifically about climatic variables, individuals may remember not skiing for an entire season because of other influencing factors (i.e. time, money, family obligations) but may now attribute their response mainly to poor snow conditions. Just over 50% of respondents indicated they stopped skiing for part of the season, 30% skied less often during a season, and 70% purchased less skiing related equipment and apparel. Just under 60% skied elsewhere within the US Northeast and 67% skied elsewhere outside of the region.

The most commonly cited individual response to marginal snow conditions that are anticipated in future seasons was to ski/snowboard more frequently to account for the shortened ski season length (79%), followed by stopping skiing/snowboarding for a full season (78%). When comparing the multiple responses defining future spatial (i.e. travel within and outside the Northeast), temporal (i.e. ski more often and ski less often) and activity-based (i.e. do something else) substitution frequencies, spatial substitution was the most common, followed by temporal and lastly activity substitution, suggesting there is a strong loyalty to the sport among participants generally. The high prevalence of individuals indicating they would travel further to ski in an area that had available or better snow conditions brings to light an interesting paradox, whereby individuals traveling in order to participate, on a per capita basis, will generate increased CO_2 emissions thereby contributing to further climate change.

When individuals were asked what they think they might do instead of skiing, if they could no longer do so, open-ended responses showed that 44% would participate in a warm-weather activity. Of those indicating likelihood to switch to a warm-weather holiday, 46% suggested they would go to the beach, 14% would golf, and 40% would do something else such as hiking, running, or biking. Of the total responses, 21% would spend more time with their family or work more, 13% would participate in passive indoor activities such as watching movies, playing video games, knitting or cooking. Nine percent would participate in active indoor activities such as working out at a gym or playing basketball or racquet sports. Interestingly, 13% would prefer to participate in other winter-based activities including snowshoeing, cross-country skiing or snowmobiling. However if marginal conditions of the future are extreme enough to cause ski areas closures, these activities are unlikely to be available (see McBoyle et al., 2007; Scott et al., 2008).

When examining the net difference between substitution behaviour of the past and intended behaviour for the future (i.e. past response minus future response), the rate of behaviour change is significantly lower than that suggested by König (1998) or by Behringer et al., (2000). Only a one percent change (+1%) is evident for individuals who ‘stopped skiing for an entire season’ in the past and for those who intend to do so in the future. Five percent fewer individuals intend to ‘stop skiing for part of the season’ under future conditions (-5%) and six percent fewer plan to ‘do something else’ instead of skiing (-6%). Slightly more significant decreases are evident within individuals who in the past ‘skied elsewhere in the Northeast’ or ‘outside of the Northeast’ region than those who indicate they would engage in the same behaviour in the future (-21% and -28% respectively), suggesting that there could be a slight decrease in future spatial substitution (Table 17). Overall substitution patterns revealed in this study indicate that although some negative consequences should be anticipated, demand for skiing opportunities is likely to remain much the same despite anticipated increases in marginal snow conditions. The potential that future generations would respond differently than this respondent group, perhaps due to less opportunity to participate and develop a loyalty to the sport, is an acknowledged possibility however.

Table 17: Past and future substitution behaviour of respondents

Type of Substitution	Past	Future	Difference
Stop for full season	78.7	79.6	+1
Stop for part season	53.3	47.8	-5.5
Ski less often	38	33.6	-4.4
Ski at higher intensity b/c of shorter season	79.1	76.8	-2.3
Ski elsewhere in Northeast	59.6	38.7	-20.9
Ski elsewhere outside Northeast	66.7	38.8	-27.9
Do something else	51.9	45.6	-6.3
Act the same	53.7	55.1	+1.4
Purchase less equipment/apparel	69.4	56.1	-13.3

Note: multiple response questions precludes responses from adding up to 100

In König’s (1998) study it was revealed that the rate of behavioural substitution differed among individuals who have expert versus intermediate or beginner skill levels. More experienced skiers were slightly less willing to give up skiing under marginal snow conditions in the future and were more likely to travel further distances where better conditions exist in comparison to beginner level skiers (König, 1998). In this study, contradictory results were found, whereby expert skiers (i.e.

specialists) were found to be more vulnerable to change and most likely to exhibit substitution behaviour (activity, spatial and temporal). Respondents who self-identified as expert skiers were more likely to stop for an entire season, or part of the season, were more likely to ski less, or do something else, and less likely to travel to ski either within or outside of the Northeast region than were intermediate or beginner skiers.

While in contrast to the limited previous studies, this finding is actually consistent with the theory of specialization developed by Bryan (1977). Individuals can be placed on a continuum from general interest and low involvement to specialized interest and high involvement depending on level of commitment to a particular activity. Specialization can be determined by amount of past experience and ownership of equipment, and is considered to influence desired settings for an activity and preferred social context (Bryan, 2000; Scott & Shafer, 2001). Within this study, the most specialized individuals (i.e. those who identified as experts and also tended to have a number of years of experience, and owned ski equipment) were more likely to engage in substitution behaviour than those who were less specialized (i.e. generally the beginners and some intermediate skiers). Specialized individuals tend to have an increased desire for particular conditions, settings, and quality of resources and are less willing to participate than less specialized individuals when these conditions are not available (Figure 12).

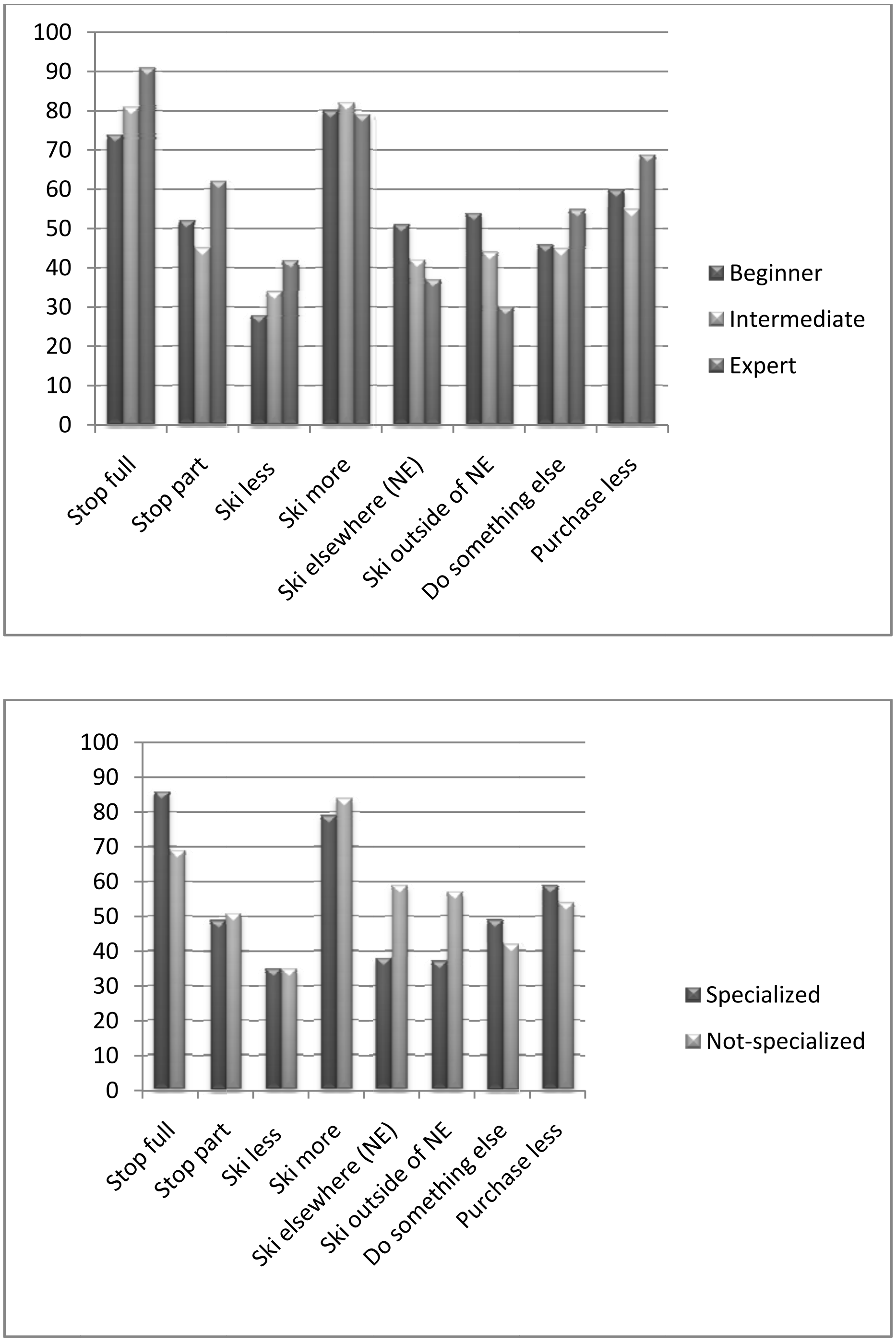


Figure12: Influence of self-rated experience and specialization on future substitution behaviour

In this study area, Dawson et al., (2009) found that size of ski area as well as elevation of ski area play a significant role in supply-side climate change vulnerability, mainly due to temperature differences at varying latitudes and altitudes. However, there is a complete absence of information regarding the influence of size and location of ski areas on climate change vulnerability for the demand-side of the sector. In this study, little evidence was found to suggest that substitution behaviour differs between participants at smaller versus larger ski areas or between ski areas located at southern and northern zones of the study area. Individuals surveyed at smaller ski areas were only slightly more prone to ski less often (38 vs. 33 %), stop skiing for all (84 vs. 82%) or part of the season (52 vs. 47%), or do something else with their time (51 vs. 43%) and were slightly more likely to ski elsewhere within (44 vs. 38%) or outside (48 vs. 36%) of the Northeast region than were individuals surveyed at larger resorts.

Similarly, individuals surveyed at ski areas located in the more northern portion of the US Northeast were only slightly more likely than those surveyed at middle or southern resorts, to stop skiing for the full season (88 vs. 81 and 84%) or for part of the season (52 vs. 50 and 45%). These skiers were also slightly more likely to ski elsewhere within (45 vs. 39 and 32 %) or outside (44 vs. 36 and 43%) of the region. Individuals at ski areas located in the southern range of the US northeast were slightly more likely than skiers at middle or northern ski areas to ski more often (85 vs. 83 and 73%) (Figure 13).

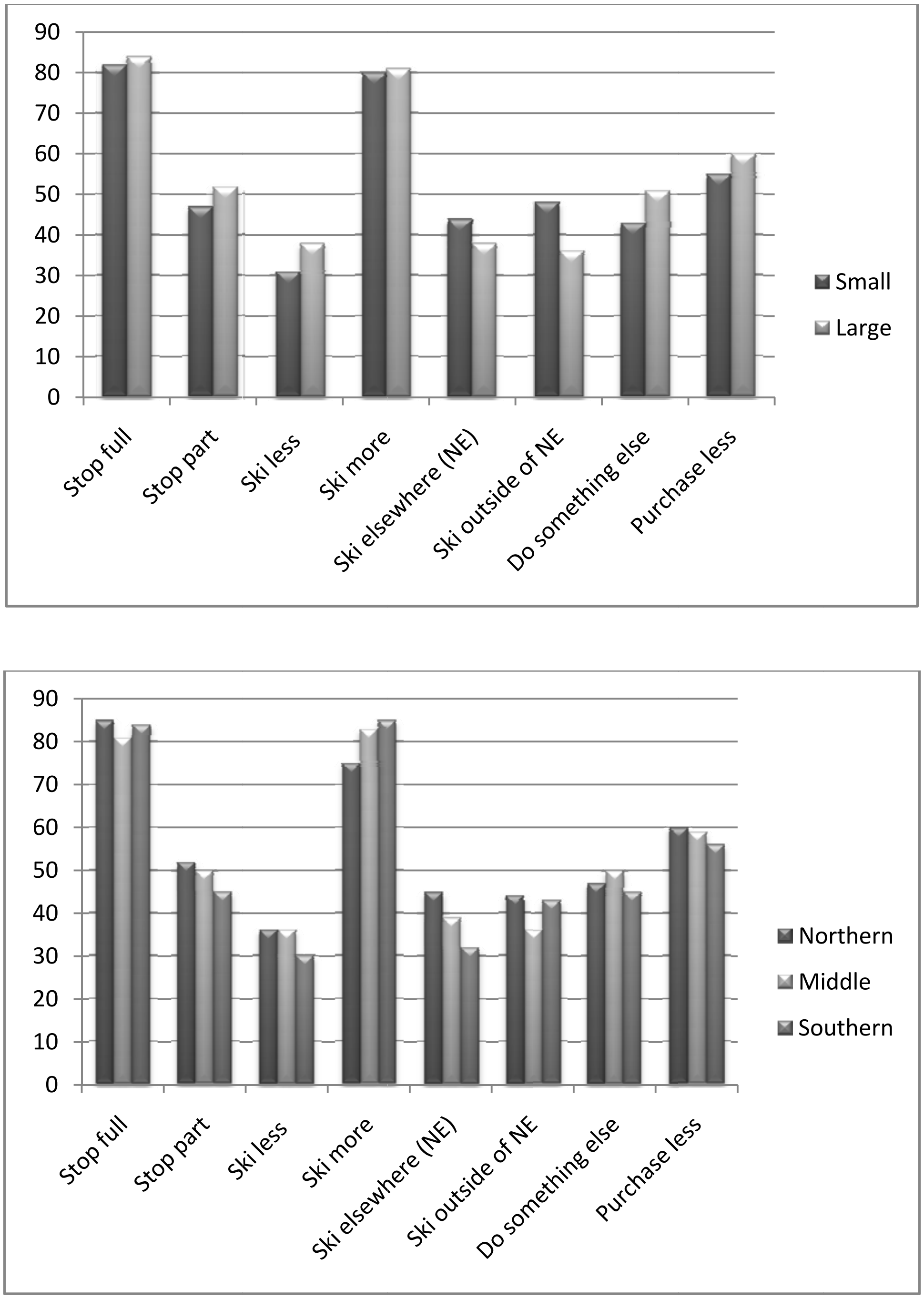


Figure13: Influence of size and location of resort on substitution behaviour

4.3.3 Factors Influencing Participation Decision Making

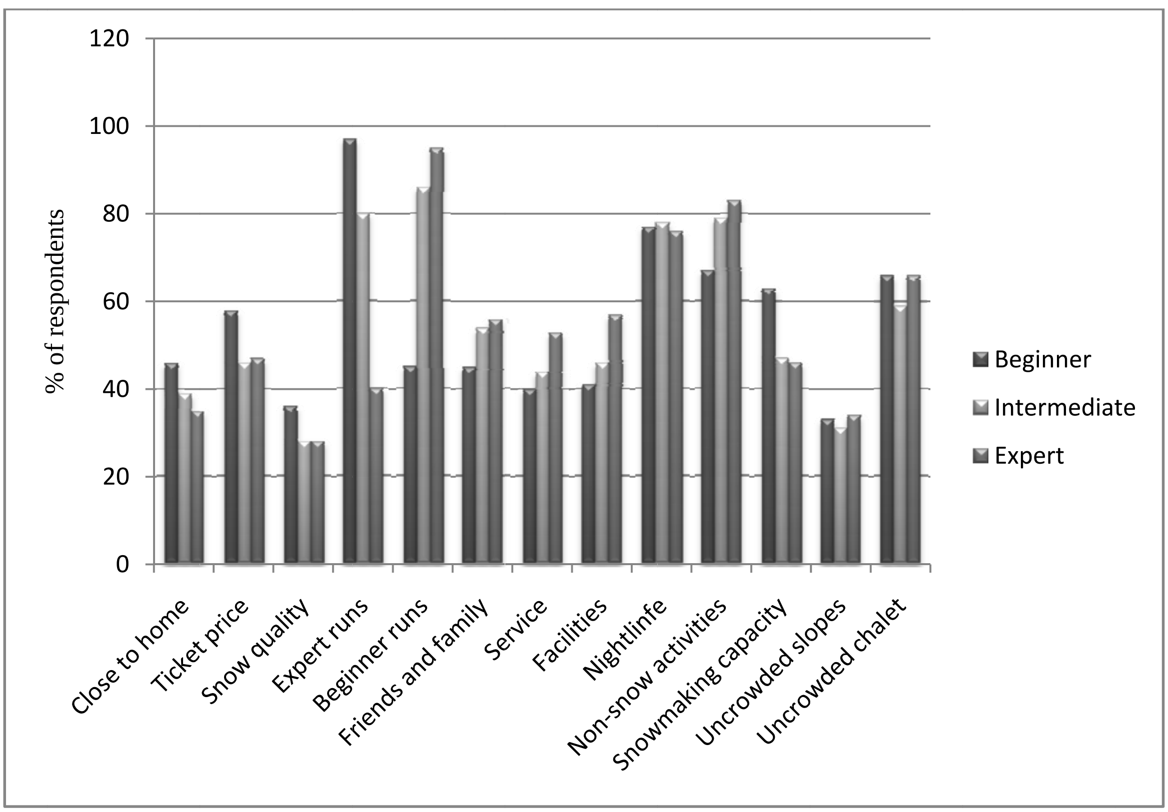
In this study, respondents were asked about structural factors that have an influence on their decision to continue skiing. Over the past three decades, ski areas in North America have been diversifying their business operations to additionally include alternative snow activities (i.e. snow-tubing, Nordic skiing, snowmobiling, skating, dog sledding) and non-snow activities (i.e. pools, health spas, fitness centers, squash and tennis courts, restaurants, bars and retail opportunities) (Scott & McBoyle, 2007). This was likely in response to a trend identified in the late 1980's, that 20-30% of visitors to ski resorts in Canada did not ski during the visit (Williams & Dossa, 1990). Diversification of the market has been very valuable for some ski areas and could be an important adaptation strategy for ski areas in an era of climate change. Scott & McBoyle (2007) point out lift ticket sales represented almost 80% of ski area revenue in 1974-75 versus only 47% in 2001-02.

In this study, the most important structural factors influencing respondents decision making to participate in the activity of skiing included presence of beginner runs, presence of nightlife, presence of non-snow-related activities (i.e. pool, snow tubing etc.) and the presence of expert runs (Table 18). Importantly, quality of snow conditions was rated as one of the least important factors influencing skiers decision to ski, which is contradictory to some previous studies that found snow conditions to be a primary factor (see Carmichael, 1996). The implications of these findings include the possibility that the addition of other activities for the winter season as well as ski area diversification into multiple-season resorts, may indeed shield ski areas from experiencing significantly reduced visitation revenues under future climate change.

Table 18: Influencing structural factors in participant decision making

Factor	Strong Influence (%)	Minor Influence (%)	No Influence (%)
Presence of beginner runs	50.0	32.2	15.3
Presence of nightlife	46.5	29	22.1
Non snow-related activities (pool)	39.2	38.1	20.2
Presence of expert runs	27.0	42.5	28.0
Friends and Family ski there	19.8	32.8	45.6
Absence of crowded facilities (chalet)	16.5	43.8	37.6
Price of tickets	12.7	33.6	51.6
Quality of Facilities	11.5	34.9	51.5
Proximity to place of residence	11.4	26.9	59.9
Snowmaking capacity	9.4	37.9	50.9
Quality of Service	8.9	36.2	52.7
Quality of snow conditions	2.9	24.5	70.8
Absence of crowded slopes	2.8	29.2	66.5

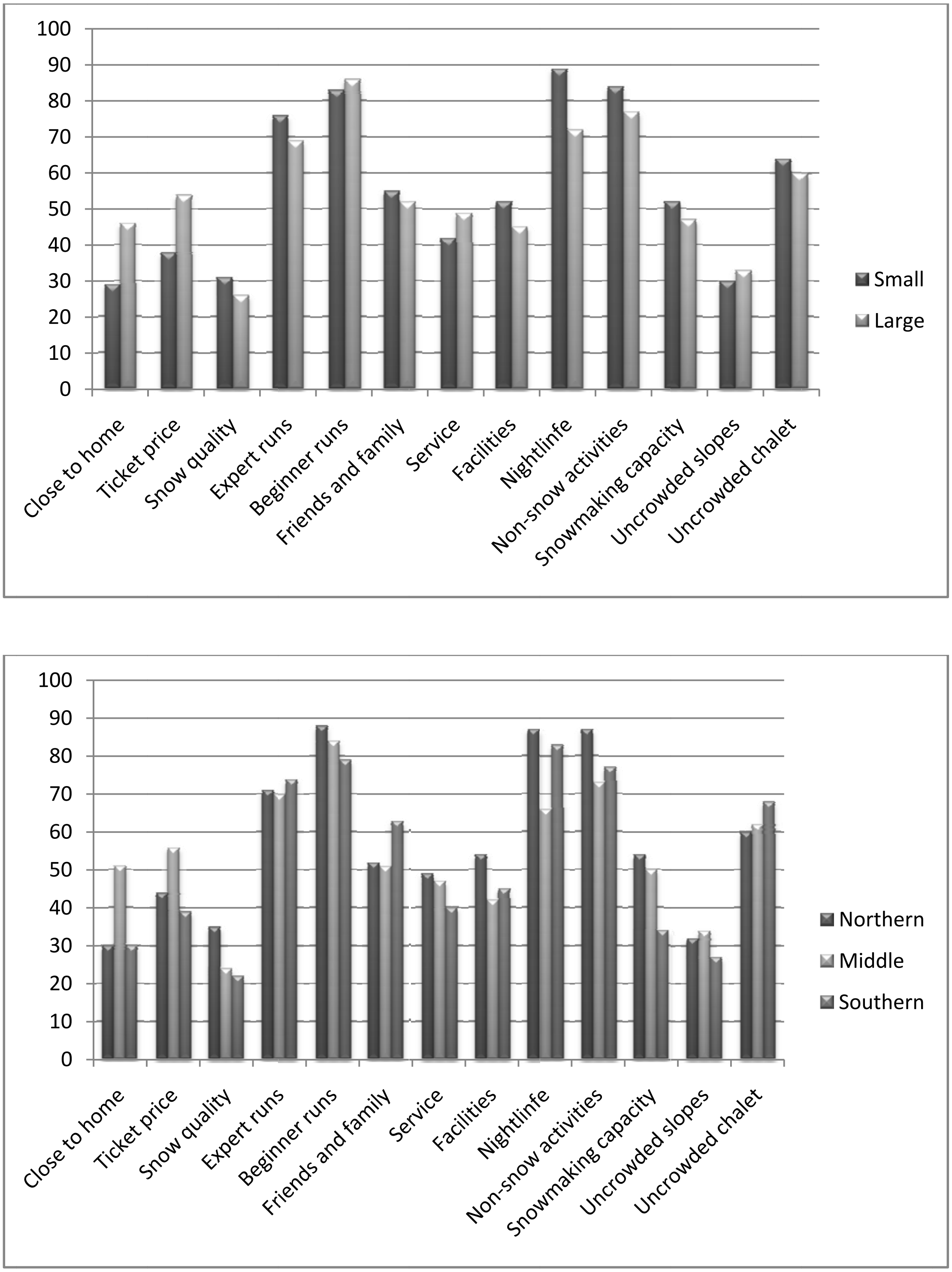
The influence that experience level has on structural preferences was also examined. Beginners rated the presence of expert runs, nightlife, non-snow activities, snowmaking capacity, and uncrowded slopes as important influencing factors in their decision to participate. Beginners also rated close proximity to place of residence, ticket price and snowmaking capacity higher than self-identified expert skiers. These factors are congruent with specialization theory, which suggest that for individuals with low or early involvement in an activity, price and ease of participation are highly important (Bryan, 1979). The notion that presence of expert runs is important to beginners could be because they anticipate improving and becoming expert skiers (see Scott & Schafer, 2001) or because they enjoy spending time with friends and family who are of all skill levels. Conversely, individuals who self-identified as experts were most influenced by the presence of beginner runs; this is possibly related to the high number of expert skiers in this study who indicated that they were skiing with their families who likely perhaps required a wider variety of terrain. Expert skiers also identified nightlife, non-snow activities and uncrowded chalets as important in their decision to ski at a particular ski area (Figure 14).



<u>Note:</u> strong and minor influences were combined to display a measure of overall influence

Figure 14: Influence of skill level on decision making factors

Size of resort and location of resort also seem to play a role in individual preferences. Respondents surveyed at smaller resorts indicated that the presence of expert runs, presence of nightlife, and non-snow activities were most important in influencing behaviour and decision making. Respondents surveyed at large ski areas were more influenced by the ski areas' proximity to their place of residence, ticket price and the presence of beginner runs. Individuals skiing at resorts in the northernmost region of the US Northeast were more influenced by the presence of beginner runs, nightlife and non-snow related activities than those at more southern resorts. The most influential factors for respondents at southern resorts were the presence of expert runs, the presence of their friends and family and the presence of an uncrowded chalet (Figure 15).



Note: strong and minor influence combined

Figure 3: Influence of size and location of resort on decision making factors

Hamilton et al., (2007) examined the influence of ‘backyard snow psychology’ on decision making for skiers at two ski areas in New Hampshire and found that snowfall at a person’s place of residence also impacts decisions to go skiing. In a study of two ski areas in New Hampshire, Hamilton et al., (2007) found that during the 2002-03 ski season the two days with the highest ski area attendance directly corresponded with the two snowiest periods in the nearby major city of Boston. This finding is of concern considering that future climate change scenarios project a decrease in natural snow availability which will be particularly evident in urban centres where the majority of people live. The influence of backyard snow psychology in this study was also evident with 73% of respondents indicating that when it snows at their place of residence they think about skiing more often than when it does not snow (i.e. cognitive influence). Fewer respondents (46%), but still almost half of all skiers surveyed, indicated that when it snows at their place of residence they actually go skiing more often (i.e. behavioural influence). The dissonance between cognitive and behavioural responses are congruent with commonly cited theories of reasoned action and planned behaviour (see Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980; Ajzen, 1985, 1991). For example, a disconnect has commonly been observed between people’s attitudes, opinions and values and how that translates into any related behaviour.

4.4 Discussion

Previous survey-based studies examining the impact of climate change on the demand-side of the ski sectors in Australia and Switzerland revealed that 70-75% of skiers would change their behaviour in some way as a direct result of marginal snow conditions expected in the future (König, 1998; Behringer et al., 2000). In a more recent survey examining the impact of climate change on skier demand, Unbehaun et al., (2008) found that just 13% of skiers would not change their regular skiing behavior if there were several winters without snow. Modeling-based studies by Fukushima et al. (2002) and Shih et al., (2009) examined the relationship between snow depth and skier visits and ticket sales respectively, revealing less significant changes in skier demand. Fukushima et al., (2002) found that an increase in average temperature by 3°C would cause a reduction in snow depth that would result in a 30% drop in skier visits in Japan. Similarly, Shih et al., (2009) found statistically significant relationships suggesting that one additional inch in snow depth results in a seven to nine percent increase in daily lift ticket sales in Michigan. In an analogue assessment of visitation, Dawson et al. (2009) also revealed a much less significant reduction in skier demand under future climate change conditions (-11% for + 4.5°C scenario).

Previous research has revealed that there is likely to be a change in skier behaviour as a direct result of climate change, however the extent of these changes is not well understood. In this study, behavioural adaptation to marginal snow conditions that have occurred in the past was compared to intended behaviour change for the future, therefore establishing an understanding of the potential net change in behaviour. In this study, only one percent of respondents indicated that they would stop skiing for an entire season compared to those that said they were already doing so, thus suggesting that the market may not change as drastically under marginal future conditions as originally suspected. However, the influence of backyard psychology is not necessarily incorporated into individual skier survey responses therefore possibly reducing the extent to which individuals may change their behaviour in the future. For example, the absence of snowfall at one's place of residence was seen to influence non-participation. Considering reduced snowfall is projected in all future timeframes, and the absence of snow will be more evident within highly populated urban centres versus less populated rural areas, it is possible that a greater proportion of individuals will decide not to ski because of the influence of poor snow conditions at their place of residence than those stating so in the survey. This finding therefore supports the analogue analysis conducted in the same region (see Dawson et al., 2009 – Chapter 2), which examined skier visitation during past marginal snow seasons in comparison to average snow seasons finding that during the analogue seasons (i.e. marginal snow seasons of the past) visitation decreased by a total of only 11%.

Between 25% and 33% more respondents indicated that under marginal snow conditions they would not travel to ski within or outside of the Northeast region respectively, in order to participate at a location that has better conditions. The majority of respondents revealed that at some point in the past when marginal snow conditions were present they had indeed traveled to other ski areas within (60%) or outside of the Northeast region (67%) to ski, indicating that although there may be a decrease in spatial substitution in the future there is still likely to be a spatially-based market shift of some degree. In fact, spatial substitution was the most commonly stated form of behavioural adaptation under future conditions (i.e. travel within or outside the Northeast), followed by temporal substitution (i.e. ski more often in shorter season or ski less often) and lastly activity substitution (i.e. do something else).

Skiing more often within a shortened ski season (temporal substitution) was the second most commonly cited individual response to marginal snow conditions for the future, but was the most frequently occurring response to past conditions. This directly corresponds with the findings of Scott

(2005), who examined skier visitation during past marginal snow seasons in the US Northeast and Ontario, and Quebec, Canada, in comparison to average snow seasons. During the climate change analogue seasons (i.e. marginal season) an unexpectedly small reduction in skier visitation was apparent in all regions, which Scott (2005) attributed to a possible increase in the frequency with which skiers participated (i.e. skiing more often in a short season in order to achieve as many trips/ski days as they would in a longer season).

Despite the respondents' indication that they would change their behaivour under marginal snow conditions in a variety of ways, the overall findings of this study suggest that the skier market is in general very resilient. In total, 54% of respondents indicated that they have not changed their skiing behaviour in the past when there have been marginal snow conditions and 55% indicated that in the future they would again not do so. However, if the ski areas that they normally ski at were forced to close due to the future challenges of climate change, these individuals would be forced to change their participation behaviour and would likely travel to another nearby resort with similar features.

The skiers in this study who were most likely to engage in substitution were those who self-identified as having expert skill levels. The application of principles described by Isa Ahola (1988) in his theory of substitutability, by Bryan (1977) through his notion of specialization and also through consideration of Homans' (1958) theory of social exchange helps to more fully articulate this finding. Specialization suggests that individuals who are more committed to a particular activity (i.e. experts) tend to require more specific resources for continued participation and avoidance of substitution-based behaviour (Bryan, 1977; Isa-Ahola, 1998). Social exchange theory additionally posits that for individuals to remain engaged in an activity they must garner rewards that are of greater value than their perceived cost of participation. These rewards change and evolve over time and as individuals become more specialized within an activity they require different rewards (Searle, 1991). It is important to remember that beginner skiers today may in the future become experts (see Scott & Schafer, 2001) and as a result would require different rewards for continued participation than they do today. This was evident in this study whereby beginners identified that the presence of expert slopes strongly influences their decision to ski at certain resorts (i.e. indicating a desire to improve). In this study, experts identified non-snow related activities as strongly influencing their decision to participate in the activity, suggesting that since they have become more specialized they require additional stimulus beyond the presence of expert, or black diamond runs to maintain their attention. Because expert skiers are more susceptible to substitution behaviour than beginners it is essential that ski areas continue to recruit new skiers into the activity to maintain a stable market of individuals who are generally less influenced by marginal snow conditions.

Individuals skiing at larger more northern resorts were marginally more susceptible to substitutability than those skiing at smaller more southern resorts which likely correspond to the higher number of skiers self-identifying as experts at the larger more northern ski areas.

4.5 Conclusion

Over ten years ago Wall (1998), suggested that, from a regional perspective, the supply-side of the tourism industry (i.e. location, infrastructure etc.) is likely to be more vulnerable to climate change than the actual tourists who travel to varying locations. According to recent research, Wall’s (1998) assertion appears correct (see Scott et al. 2003; Dawson et al., 2009; Chapter 3); however, it may be more accurate to state that the impact that climate change has on the demand-side of the sector is likely to play a significant role in determining the net vulnerability of the supply-side. For example, Dawson & Scott (Chapter 3), project a decrease in the number of ski areas in the US Northeast by 40-65% in the 2040-69 time period, and if the demand for skiing does not decrease proportionally to the decrease in supply, as the findings of this study suggest, then the remaining ski areas and adjacent communities would need to plan for increased market share and visitation. This type of market shift could cause peak season crowding issues and influence real estate development (i.e. second homes, condominiums and time shares) causing a rise in housing prices for locals, a change in regional taxes, and even increased need for social services as well as increased pressure on environmental resources. In turn, the communities that lose ski tourism operations will need to develop economic diversification strategies and could also see increased pressure on social services and unemployment as well as a drop in real-estate value (see Hamilton et al., 2007; Scott et al., 2008).

Focusing on the highly climate-sensitive ski tourism industry both Hamilton et al., (2007) and Scott et al., (2008) identify that it is not just the individual operators that need to plan for climate change, but it is also the surrounding communities that rely on the industry. Hamilton et al., (2007) in particular point out that the vulnerability extends beyond even community-based employment and livelihoods suggesting that operating ski areas are regularly the main economic engine for entire rural areas. In order for ski area operators and nearby communities to successfully plan and implement climate change adaptation strategies, understanding that there is likely to be a shift in current market demand (i.e. through substitution behaviour), and that market segments will engage in a different types of substitution behaviour (spatial, temporal, activity) could be very valuable. Ski operators and communities should expect at least a small to moderate market-shift under future warming conditions and plan accordingly. Under future conditions whereby the most vulnerable ski areas are indeed expected to cease operation, remaining ski areas will likely see an increase in market share, which may occur more rapidly than they are able to plan for. Suggested adaptation strategies to be implemented by ski areas in order to maintain demand-side stability while minimizing substitution behaviour include, improving weather forecasting and reporting, developing off-season and shoulder season offerings (Scott &McBoyle, 2007), providing accessible and convenient transportation to ski areas, providing off-site ticket purchasing, offering all-inclusive beginner packages and improving traffic information (Williams & Fidgeon, 2000). In addition, ski areas now, and in the future more than ever, should focus strongly on the family unit which makes up the largest portion of the skier market (Williams & Fidgeon, 2000) and includes very important new/beginner skiers who appear more resilient to poor snow conditions than experienced skiers. Other adaptation strategies found to be important in this study reiterate earlier suggestions by Scott & McBoyle (2007) that the presence of non-snow related activities such as snow-tubing, spas, bars and pools are vital in order to maintain the attention and loyalty of all skiers.

In this study, theoretical behaviour constructs from social psychology and leisure studies including past experience, specialization, and leisure constraints proved useful in explaining self-reported climate-induced substitution behaviour and that which can be expected in the future. Future research in the area of climate change and demand-side vulnerability for the ski tourism sector should be mindful of the usefulness of theoretical constructs and should consider drawing further upon the fields of social psychology and leisure studies. For example, this study elucidated that substitution behaviour seems to be influenced by specialization, past experience and skill level but it remains unclear the extent to which loyalty, sometimes referred to as ego involvement, or place attachment play a role in altering behavioural adaptation/substitution tendencies. Commitment and loyalty often develop through repeat visitation, satisfaction during participation, and the absence of conflict or constraint. Leisure constraints, such as those identified in this study (i.e. lack of time, money, snow or opportunities) can significantly impact an individual's level of participation or non-participation (Crawford & Godbey, 1987; Henderson, et al., 1988) and consequently the development of loyalty to the activity or to a place. Questions that remain include: how does commitment to the activity of skiing influence climate-induced behaviour change, how does place attachment or loyalty to a particular service provider/ski area influence climate-related substitution behaviour, and what differences exist between place attachment/loyalty to service providers between smaller and larger ski areas?

Chapter 5: The Influence of Involvement and Loyalty on Climate-Induced Substitution Behaviour of Skiers in the US Northeast

Very few studies have examined the impact that climate change is expected to have on the demand-side of the ski tourism sector. Existing studies examine the extent to which individuals will change their participation behaviour in response to marginal climate conditions projected under future climate change scenarios. This study builds on the limited understanding of climate-induced behaviour change by examining the influence that ego-involvement and commitment/place attachment plays on substitution behaviour in US Northeast ski region. Two commitment scales were employed (Modified Involvement Scale and Psychological Commitment Instrument) to develop clusters of participants based on activity involvement (low, medium and high) and place loyalty. Individuals exhibiting high levels of involvement (i.e. commitment to the activity of skiing) were found to be more likely to change their skiing behaviour as a result of climate change than individuals with low levels of involvement. Highly involved individuals were found to ski at five times the frequency than less involved individuals suggesting that it will be vital for ski area operators to develop adaptation strategies to reduce climate-induced substitution behaviour, particularly within individuals who are the most committed to the activity. Clear place-loyalty clusters could not be established within this study; therefore the extent to which loyalty to a particular ski area plays a role in influencing substitution behaviour under future climate change remains an area for future research.

Keywords: ski tourism, demand, climate change, US Northeast, ego-involvement, loyalty, place-attachment

5.1 Introduction

The international ski industry has, in recent years, received increasing media and academic attention due to the sector's perceived vulnerability to climate change (see Scott, 2005 and Scott et al., 2008 for a summary of research). In March of 2008, over 240 researchers from around the world attended the fifth World Congress on Snow and Mountain Tourism held in Encamp, Andorra to specifically discuss the implications of climate change for the international ski tourism sector. In a key note address, past Secretary General of the World Tourism Organization [WTO] Franchesco Frangialli quoted climate change projections developed by the Intergovernmental Panel on Climate Change [IPCC] that suggest temperature is likely to rise between 2°C and 4°C by the end of the century, before emphasizing that expected changes in climate will require "*long term visioning and adaptive planning within the ski tourism sector*". Many national ski area associations have already begun to plan for the possible impacts of climate change, including the US National Ski Areas Association [NSAA] which adopted an 'Environmental Charter' in 2000 as a commitment to responsible environmental stewardship. As part of this commitment, the 'Keep Winter Cool" campaign was launched in 2002 and a 'climate change policy' was adopted, whereby the association and members pledged to educate ski resort visitors about climate change, invest in a range of energy efficient and alternative energy projects, and reduce operational greenhouse gasses [GHG] (NSAA, 2009). Scott et al., (2006) hypothesize that the increased "*interest in climate change [by ski areas] is partly a function of press coverage of research that has identified significant vulnerabilities in eastern North American sites to even modest changes in temperature and precipitation*" (p.337).

Supply-side assessments of climate change vulnerability for the ski sector in eastern North America have included projections of decreased natural snow reliability often resulting in decreased season length, increased snowmaking requirements, increased operating costs and decreased revenues in association with decreased visitation (see Scott et al., 2003, 2006, 2007; Dawson & Scott, 2007; Dawson et al., 2009). Scott et al., (2008) and Dawson & Scott (this manuscript – Chapter 3) anticipate a contraction of ski areas across the US Northeast as ski area managers are no longer able to afford the cost of adaptation expected under future climate change scenarios.

Studies examining climate change vulnerability for the supply-side of the ski sector have also been conducted in Australia, Japan and across Europe (Australia - Galloway 1988, Hennessy et al., 2003, Bicknell & McManus, 2006; Austria - Breiling & Charamza, 1999, Wolfsegger et al., 2008, Abegg et al., 2007; France - Abegg et al., 2007; Germany - Abegg et al., 2007; Italy - Abegg et al., 2007; Japan - Fukushima et al., 2002 ; Sweden - Moen & Fredman, 2007; Switzerland - König & Abegg, 1997, Elsasser & Messerli, 2001, Elsasser & Bürki, 2002).

Contrary to the attention given to analyzing climate change impacts for the supply-side of the ski sector, very few studies have considered how climate change might impact ski area demand. König (1998) utilized surveys to examine how skiers might respond to hypothetically poor snow conditions in the future, finding that 25% of skiers would continue skiing at the same place and frequency, 31% would ski less often, 38% would ski at another overseas location and 6% would quit skiing altogether. Similar surveys were conducted by, Behringer et al., (2000) and Bürki (2002) to examine skier responses at resorts in Switzerland. Behringer et al., (2002) found that 30% of respondents would not change their skiing behaviour, 11% would ski at the same location but less often, 28% would ski at a more snow reliable resort at the same frequency, 21% would ski at a higher resort less often, and 4% would give up skiing altogether. Bürki (2002) found that the majority of skiers would ski at the same frequency (30% at same resort 28% at another snow reliable resort), 32% would ski less often, and four percent would stop skiing.

In the US Northeast region, Dawson et al., (2009– Chapter 2) used an analogue assessment to examine the impact of climate change on ski area demand revealing just an 11% decrease in visitation during a winter season representative of mid-range emissions scenario for the 2040-69 time period (+4.5°C). Scott (2005) found similar reductions in visitation when conducting climate change analogue assessments of ski area operations in Ontario (-7%) and Quebec (-10%). Scott (2005) attributed the low reduction in skier visitation to temporal substitution, whereby skiers skied more frequently in a shortened season. The notion of greater utilization during shorter ski seasons in the US Northeast suggests that some level of behavioural climate-induced adaptation is indeed occurring. This led Scott & McBoyle (2007) to recommend survey research examining behavioural adaptation of skiers, "*in order to better understand adaptation decision making and how adaptation differs among segments of the ski market (e.g. core vs. occasional skiers)*" (p.1424). Furthermore, Dawson (2007) and Scott et al., (2008) have suggested that well-established and readily available leisure behaviour concepts could be particularly useful in examining and explaining climate-induced behaviour change.

Iso-Ahola's (1986) theory of 'recreation substitution' is particularly relevant to the examination of climate-induced behaviour change within the ski tourism sector. The 'theory of substitutability' suggests that when individuals are no longer able to participate in an activity (i.e. for example, due to the absence of local ski areas) they generally substitute that activity with another. Since the theory's inception, conceptualizations and applications have forced its divergence into three main streams including activity substitution (i.e. Iso-Ahola's original definition), spatial substitution, which entails participating in a different location than originally intended, and temporal substitution, which involves participating at a different time or at a different intensity than originally intended (see Hall & Bo, 2000; Gilbert & Hudson, 2000).

It has been suggested that differences in an individual's level of experience or personal involvement in a particular activity can have a strong influence on participation behaviour (Bloch, et al., 1989; Havitz & Dimanche, 1990). The extent to which individuals would change their level of skiing participation due to climate variability has been directly linked to self-reported skill level (i.e. level of experience or specialization – Bryan, 1977). For example, König (1998) and Behringer et al., (2000) in their explorations of climate change influences on skiing demand in Australia and Switzerland found that expert skiers were disproportionately more likely to continue skiing despite marginal snow conditions than were beginner level skiers. However, the extent to which commitment to the activity of skiing, or to a particular ski area would influence climate-induced substitution behaviour during marginal snow conditions expected in the future was not considered.

The examination of leisure involvement (i.e. commitment) and loyalty to service providers has utility for both professional practitioners, who desire to better understand their target market, as well as for academics attempting to increase comprehension of leisure behaviour generally, or within certain contexts (Kyle et al., 2007). The focus of leisure research has generally been on examining involvement in specific activities (i.e. skiing, golf, travel), with particular service providers (i.e. golf clubs, ski areas, airlines) or brands (i.e. Dunlop, Whistler, Delta) (Havitz & Dimanche, 1990). Definitional debates about the terms 'involvement' and 'loyalty' are evident within this literature which continues to elicit evolving conceptualizations of the differences and similarities between terms, among others including commitment, attachment, attitude and value (Jarvis & Mayo, 1986; Backman & Crompton, 1990; Mo et al., 1992; Havitz & Dimanche, 1990; Prichard et al., 1999; Kyle et al., 2007). Although conceptual debates continue, 'involvement' has traditionally been used in academic literature to examine leisure activities, where 'loyalty' is seen as a common measurement for investigating commitment to specific service providers and/or brands (see Dimanche & Havitz, 1994; Kyle et al., 2007).

Involvement is commonly defined as an unobservable or intrinsic state of interest, evoked by a particular stimulus, situation or both (Rothschild, 1984), and is generally composed to two forms including, 'enduring', which reflects a sustained level of attachment, or 'situational', which involves fluctuating attachment stimulated by specific situations (Houston & Rothschild, 1978; Bloch et al., 1989; Richins & Bloch, 1986; Havitz & Howard, 1995). Involvement is understood to be a complex construct encompassing a variety of dimensions, which have been rigorously debated in academic literature for several decades (Rothschild, 1984; Laurent & Kapferer, 1985; Dimanche & Samdahl, 1984; McIntyre, 1989; Dimanche et al., 1991; McIntyre & Pigram, 1992; Havitz et al., 1994; Havitz & Dimanche, 1990; Kyle & Chick, 2002, 2004; Havitz & Howard, 1995; Kyle et al., 2003, 2004a,b, 2007).

The Modified Involvement Scale [MIS] developed by Kyle et al., (2007) employs multiple dimensions which have been validated through previous research. The multiple dimensions included in the scale are; *attraction*, *centrality, social bonding, identity affirmation,* and *identity expression*; which collectively measure overall involvement. *Attraction* measures the importance of an activity to an individual including the amount of pleasure they derive through participation. C*entrality* refers to 'centrality to lifestyle', measuring the extent to which individual lifestyle choices and personal investments (financial and social) are made to support continued association with an activity (Wellman et al., 1982; McIntyre, 1989). In addition to individual lifestyle choices, involvement within social networks has been proven to inspire continued involvement in a particular activity, thus the dimension *social bonding* is included in order to measure the extent to which involvement is driven by important social ties (Kyle & Chick, 2002; Kyle et al., 2007). Identity is also thought to play a large role in activity involvement through both the ability to express oneself through *identity affirmation,* as well as the opportunity to express oneself to others through *identity expression* (Haggard & Williams, 1992; Dimanche & Samdahl, 1984). Particular activities are thought to invoke certain images for individuals; for example being a snowboarder versus a skier may be seen as more desirable to some who have developed a positive association with the image of snowboarding.

The Alpine ski industry is considered by some to have entered a mature phase (Pechlaner & Tschurtschenthaler, 2003; Matzler et al., 2007) and is anticipated to experience market-level decline. This phenomenon is likely to be exacerbated by climate change. For example, as ski area operators become unable to afford the future costs of adaptation (i.e. snowmaking technology and costs of operation), the market is likely to contract (i.e. lost ski areas), which could cause congestion and crowding at remaining ski areas (Scott et al., 2008; also see Chapter 2). Yoon & Uysal (2005) suggest that success of a destination operating within a saturated market (i.e. crowded), very strongly depends on a thorough understanding of tourist motivation, satisfaction and most importantly loyalty. Considering loyalty is thought to be of great importance to organizational success and profit (Oliver, 1997) the examination of loyalty to individual ski areas under future climate change conditions seems an important area of research.

Prichard & Howard's (1993) Psychological Commitment Instrument (PCI) provides a rigorous measure of tourists' commitment to service providers (Dimanche & Havitz, 1994) through measurement of several antecedent processes thought to collectively evaluate loyalty. The scale measures both consumer purchase behaviour as well as attitude towards a service, thus moving beyond the criticized single dimension scales that measure only repeat purchases (see Jacoby & Chestnut, 1978; Prichard et al., 1999). The multiple items measured within the scale include, *resistance to change, position involvement, volitional choice,* and *informational complexity*. An individuals' *resistance to change* is considered central to the development of loyalty and is at the core of the scale. Similar to identity affirmation (MIS), *position involvement* is evident when an individual's values or self-images are identified within a particular service provider. The link between a preference and one's personal values and self-images is thought to strengthen resistance to change. *Volitional choice* is the ability to make decisions freely and in the absence of constraints. When perceived volition is high individuals are thought to feel more personally responsible for their decision than when perceived volition is low (Salancik, 1977). Loyalty is also thought to be related to *informational complexity,* or how knowledgeable an individual is about a particular service provider. Resistance to change can be driven by a desire to avoid dissonance regarding what one believes or feels about a particular service. For example, persuading an individual of something contrary to what they believe to be true about a service provider is thought to be more difficult as an individual becomes more knowledgeable and committed.

This study uses a cluster analysis approach to examines the extent to which involvement in the activity of downhill skiing, and loyalty to particular ski areas in the US Northeast influences the rate of climate-induced substitution behaviour under future climate change scenarios. Skiing in the US Northeast is both culturally and economically important. Some of the earliest operating ski areas were established in the region, which currently attracts over 13 million skiers in a season (NSAA, 2007). The US Northeast includes the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont and consists of over 100 ski areas with mid-range elevations ranging from 137 metres above sea level (masl) to 1353 masl (NSAA, 2008; USGA, 2008). Individuals ski an average of 10 times per season in the US Northeast, which is the highest participation rate in the country (National Sporting Goods Association, 2005).

5.2 Methods

During the months of January and February, 2007 skier surveys were self-administered in ski chalets and cafeterias at six selected ski areas. Ski area selection was based on four factors including; 1) geographic location within the US Northeast region (i.e. north, middle, south), 2) elevation of ski areas (i.e. vertical drop), 3) size of resort (i.e. smaller vs. larger resorts), and 4) proximity to major urban centres (i.e. Boston, Buffalo, New York, Montreal). All six selected ski areas allowed surveys to be distributed on premises, making operator participation 100%. Two of the six resorts were located in the north of the region, two in the middle and two in the south. Four were considered smaller ski areas (i.e. <1500 ft vertical drop) and were located at lower elevations, and two were considered larger resorts (>1500 ft vertical drop) located at higher elevations. Of the 1,309 distributed surveys 1,167 were returned representing an 89% response rate. Nine surveys were considered invalid and discarded leaving a total of 1,158 analyzed responses. In total, 452 (39%) surveys were collected at northern ski areas, 479 (41%) from ski areas located in the middle of the region and 227 (20%) from ski areas in the south. Because larger ski areas are able to accommodate more skiers over a proportional amount of time 692 (60%) surveys were collected, versus 466 (40%) from smaller ski areas (see Figure 10, Chapter 4).

In order to understand how individuals are impacted by marginal snow conditions, respondents' were asked how they would change their skiing behaviour in response to poor snow conditions in the future (i.e. stop skiing, ski somewhere else, ski less often, ski the same etc.). In order to measure the extent to which activity involvement or place loyalty plays a role in influencing climate-induced behavioural adaptation, two previously validated behavioural psychology scales were employed in the survey. Kyle et al.'s (2007) Modified Involvement Scale (MIS) was used to examine activity involvement and Prichard et al.'s (1999) Psychological Commitment Instrument (PCI) was used to measure loyalty to ski area service providers. Demographic information including skier habits and trip characteristics were also examined.

Survey pre-tests (n=15) determined that inclusion of the full MIS and PCI scales, in addition to the behavioural substitution questions, made the instrument slightly too long to maintain respondent attention and threatened response rate. Therefore the behavioural psychology scales (MIS, PCI) were reduced from 15 and 12 items to 10 and eight respectively. One item from each dimension within both the MIS (*attraction*, *centrality, social bonding, identity affirmation*, *identity expression*) and PCI (*resistance to change, position involvement, volitional choice, informational complexity)* scales was eliminated based on the lowest R^2 value in the original research (see Prichard et al., 1999 and Kyle et al., 2007). An examination of alpha scores for the reduced scales indicated high consensus among questions suggesting the scales performed well despite this reduction (Table 19).

Table 19: Internal consistency of the MIS and PCI

Activity Involvement (MIS)	Cronbach's Alpha	Place Loyalty (PCI)	Cronbach's Alpha
Attraction (a and b)	0.88	Resistance to Change (a and b)	0.84
Centrality (c and d)	0.93	Position Involvement (c and d)	0.89
Social Bonding (e and f)	0.60	Volitional Choice (e and f)	0.54
Identity Affirmation (g and h)	0.79	Informational Complexity (g and h)	0.74
Identity Expression (i and j)	0.84	n/a	n/a

5.3 Results

Based on Iwasaki & Havitz's (1998, 2004) conceptual model suggesting that activity involvement is an antecedent to commitment, a K-Means Cluster analysis was conducted for activity involvement using the five dimensions of the MIS. After exploring several possibilities, three clear clusters were established representing low, medium and high activity involvement. The Medium Involvement group is the largest cluster representing 47% of respondents (n=545), followed by the Low Involvement group with 30% (n=342) and the High Involvement group which included 23% of the sample (n=258). Activity involvement clusters were analyzed further using descriptive statistics and cross tabs in order to determine the extent to which each cluster (low, medium, high involvement) adapts their skiing participation behaviour during marginal snow conditions projected under future climate change scenarios.

Using the four dimensions of the PCI, another K-Means Cluster analysis was employed in an attempt to establish clusters based on place loyalty. However, no clear groups could be established despite attempts to split the sample into two, three, four, five and more clusters.

5.3.1 Activity Involvement Clusters

Individuals can become committed to particular activities, and related materials for participation within an activity, through a series of three basic developmental stages. Firstly, a high level of physical involvement is developed, followed by the establishment of psychological commitment, and finally, the maintenance of strong attitudes toward resistance to change preferences (Iwaskaki & Havitz, 1998). The “High Involvement” cluster in this study includes individuals who have progressed through these commitment stages and as a result are thought to be highly involved in the activity of skiing. Individuals in the “Low Involvement” cluster do not exhibit this type of ‘enduring involvement’ within the sport of skiing evidenced in part by the low frequency with which they participate in the activity (mean = 6 days/yr.). However their participation in the activity at all suggests they exhibit at least some level of involvement in comparison to an individual who has never skied and does not intend to. Similarly, the “Medium Involvement” cluster, despite having lower mean involvement scores than individuals in the High Involvement cluster, are also likely to exhibit some level of situational involvement in the activity of skiing which over time may develop into enduring involvement, may remain stable or may even decline (Richins & Bloch, 1986; Havitz & Dimanche, 1990; Naylor, 2006).

The cluster analysis clearly delineates individuals who exhibit high, medium and low involvement through progressively reduced scores within all of the MIS scale dimensions. The mean score for *attraction*, or the importance of an activity to an individual’s life, is 4.9 on a scale of 5 for individuals in the “High Involvement” cluster; this drops to 4.0 and 3.2 respectfully for Medium and Low involvement clusters. The extent to which lifestyle choices are made to support continued association with skiing (*centrality*) is very high for the High Involvement cluster (mean score = 4.3) and fairly low for the Low Involvement cluster (mean score = 1.8), with Medium Involved individuals falling in the middle (mean score = 2.8). The *social bonding* dimension produced the lowest mean score compared to all other MIS dimensions for the High Involvement cluster (n=4.1) but was still significantly higher than scores for the Medium (n=3.4) and Low (n=2.7) Involvement clusters, where social bonding represented both of the those groups second highest mean scores. The ability to express oneself through skiing (*identity affirmation*) was the second highest scale dimension for the High Involvement cluster (mean score = 4.4). Mean scores for the Medium and Low Involvement clusters were 3.4 and 2.4 respectively. Mean scores examining the importance of expressing oneself to others (*identity expression*) was 4.1 for the High Involvement cluster, 3.0 for Medium Involvement and 1.8 for Low Involvement (Table 20).

Table 20: Mean activity involvement scores (MIS dimensions)

	High Involvement Cluster (n=258)	**Medium Involvement Cluster (n=545)**	**Low Involvement Cluster (n=342)**
Attraction (items a & b)	4.9	4.0	3.2
Centrality (items c & d)	4.3	2.8	1.8
Social bonding (items e & f)	4.1	3.4	2.7
Identity affirmation (items g & h)	4.4	3.4	2.4
Identity expression (items i & j)	4.1	3.0	1.8

Note: Mean scores are statistically significant between clusters for all the facets (p< 0.001)

5.3.2 Demographic and Behavioural Characteristics of Involvement Clusters

The demographic categories examined in this study include age, education and gender. No significant differences between clusters were found for education (p=0.417) or gender (p=0.321) which is consistent with much of the existing involvement literature (see Madrigal et al., 1992; Hammer, 1997; Havitz et al., 1994; Havitz & Howard, 1995; Kerstetter & Kovich, 1997; Park, 1996; Siegenthaler & Lam, 1992). Some differences were found between involvement and age (p<0.002) which is consistent with some involvement literature (e.g., Havitz & Howard, 1995). Individuals between the ages 18 and 24 as well as those 60 and above were found to be disproportionately more involved in skiing than those between 25 and 59. Closer examination of scale dimensions reveal that individuals between 18 and 24 rated *identity expression* or the image they portray to others by participating in the activity of skiing as significantly higher in comparison to other age categories. Conversely, respondents aged 60+ had high mean *centrality* and *social bonding* scores compared to other age categories.

Behavioural characteristics including self-rated skill level, amount of skiing experience in years, and possession of a seasons pass, all differed significantly between involvement clusters (p<0.001). Very clear differences are apparent between individuals self-reporting as beginner versus expert skiers. Only three percent of individuals in the High Involvement category consider themselves to be beginners compared to 60% who rated themselves as experts. Comparatively, just four percent of individuals in the Low Involvement cluster considered themselves experts whereas 49% self-identified as beginners. This finding is intuitive and congruent with previous involvement research where self-rated skill-level was seen to play a significant role in differentiating levels of involvement within a particular activity (see Havitz & Howard, 1995). Experience, examined by number of years individuals participate in the activity of skiing, provides a direct relationship between increasing involvement scores and years of participation. Minor deviations are apparent within this trend for individuals who have 11-15 years experience (i.e. trend reverses itself and then continues thereafter). This anomaly could in part be explained by the activity life-cycle stage, which suggests that individuals who may normally be within this experience range may exhibit decreased activity involvement while raising a family or developing career aspirations (Gilbert &Hudson, 2000). Within the High Involvement cluster, 17% of individuals reported having just 1-5 years experience, compared to 33% of individuals who have over 25 years experience. The Low Involvement cluster includes 35% of individuals with 1-5 years experience compared to just 16% of individuals with 25+ year's experience.

Purchase behaviour was once considered the sole indication of commitment before a greater understanding of the complexity associated with involvement was revealed to include psychological as well as behavioural dimensions (see Havitz & Dimanche, 1990; Prichard et al., 1999). Just over 60% of individuals within the High Involvement cluster possessed a seasons pass compared to only 8% of the Low Involvement cluster. Despite this strong correlation, season pass purchase should not be used as an indication of involvement even within a more crude examination of commitment for the ski sector. Qualitative comments revealed that some individuals purchase season passes not because they are committed skiers but rather because it decreases anxiety about what they are getting in return for their money. For example, one respondent stated,

> "*I only ski a few times a year but I buy a season pass so I don't have to worry about wasting my money when there are bad conditions…I used to stress about how much I was getting out of my money and now I can enjoy myself more despite the weather*"

Considering regional climate change projections anticipate increasing marginal snow conditions it is possible that more individuals will begin buying season's passes for this reason, which does not necessarily correlate with an increase in involvement in the activity of skiing. This issue provides a segue into questions of weather and climate-induced behavioural substitution.

5.3.4 Activity Involvement and Behavioural Substitution

In this study, individuals were asked to identify how they would react if the next 3 out of 5 winters had very little snowfall (i.e. similar to marginal conditions seen in the 2001-02 season). Behavioural adaptation options included stop skiing for an entire season, stop skiing for part of the season, travel to another resort in the Northeast region to ski, travel outside the Northeast region to ski, ski less often, ski more often, participate in an alternate activity, or purchase fewer skiing related items. All of the substitution options were found to significantly differentiate the Involvement groups ($p < 0.005$). The Medium Involvement group is the most likely to change participation behaviour based on marginal snow conditions, displaying the highest mean scores for all categories except '*ski less often*'. The Low Involvement group was the least likely to change their behaviour in response to climate change conditions and the High Involvement group fell in the middle (Table 21).

Table 21: Involvement and substitution behaviour (% between groups)

Type of Substitution Behaviour	High Involvement	Medium Involvement	Low Involvement
Stop for full season (x^2=50.0, df=4, p<0.001)	34	47	19
Stop for part season (x^2=35.6, df=4, p<0.001)	38	42	20
Do something else (x^2=35.5, df=4, p<0.001)	39	42	19
Ski elsewhere in Northeast (x^2=39.5, df=4, p<0.001)	25	44	31
Ski elsewhere outside Northeast (x^2=68.3, df=4, p<0.001)	20	47	33
Ski less often (x^2=39.0, df=6, p<0.001)	41	39	20
Ski more often (x^2=45.6, df=4, p<0.001)	26	49	25
Purchase less apparel (x^2=46.7, df=4, p<0.001)	38	42	18

Note: this was a multiple response question

These findings are likely, in part, related to the frequency in which each cluster participates in the activity of skiing. In this study, the High Involvement cluster had on average participated for 31 days, the Medium for 10, and the Low for 6, at the time of data collection (late January, early February). This finding supports the long standing notion that higher involved patrons tend to participate in a given activity at a higher frequency than lower involved individuals (Venkatraman, 1988; McIntyre, 1992; Bright & Larson, 1991; Backman & Compton, 1989; McCarville et al., 1993; Bloch, 1993; Green & Chalip, 1997; Park, 1996; Schuett, 1993). This relationship has been repeatedly validated under normal conditions, however has not been examined under the influence of a significant constraint such as climate change. Because the High Involvement cluster participates at a frequency that is five times greater than that of the Low Involvement cluster, they inevitably have much more at stake when considering marginal future ski conditions, which are expected to not only influence snow conditions but also the closure of many local ski areas (Scott et al., 2008; Dawson & Scott, this manuscript – Chapter 3). If skiing opportunities are unavailable or if snow conditions are particularly marginal, individuals who are highly involved in the activity of skiing will be forced to make proportionally more decisions regarding participation than those who are already less involved.

This may also, in part, explain why activity substitution (i.e. do something else) as well as temporal substitution (i.e. ski less or ski more) was found to be higher for the High Involvement cluster (49%) than for the Low Involvement cluster (28%), whereas spatial substitution (i.e. travel to another location within or outside of the US Northeast) were higher amongst the Low Involvement cluster. In addition, *social bonding* was rated as the second highest involvement dimension for the Low Involvement cluster suggesting these individuals may be more likely to change their participation behaviour because of the presence or absence of social opportunities than because of changing future climate conditions (Figure 16).

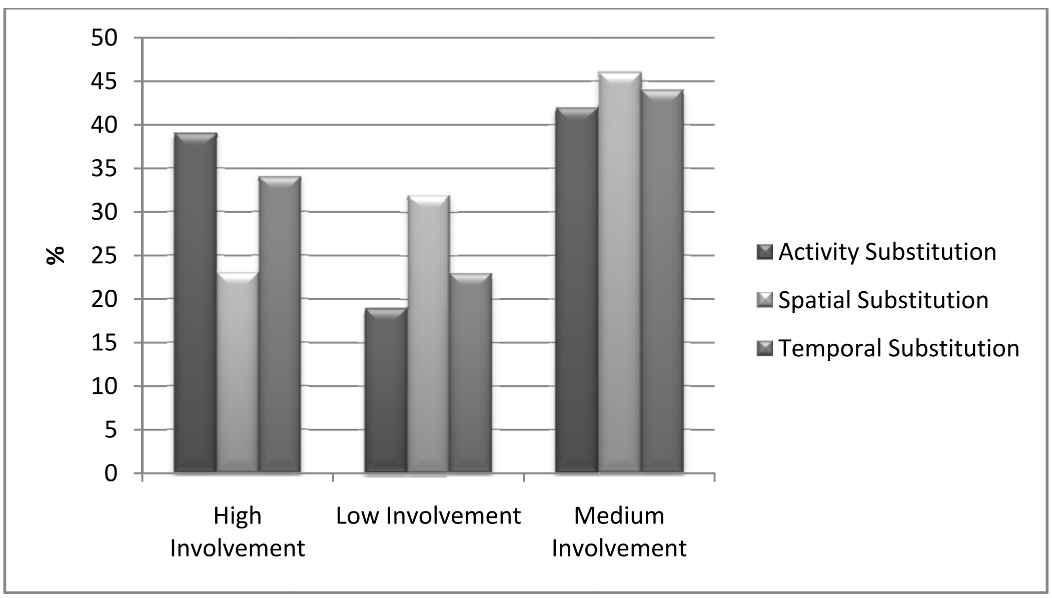


Figure 16: Influence of involvement by type of substitution behaviour

Social judgment theory, which involves examining aspects of attitude change including latitude of acceptance or rejection based on particular situations or influencing factors, is also thought to play a strong role in the behavioural response of highly involved individuals (Sherif, et al., 1965). Sherif et al., (1965) suggested that individuals exhibiting higher levels of activity involvement have narrow ranges of acceptance and broad ranges of rejection relative to those who are less involved. Highly involved individuals tend to seek out and therefore draw upon more information when making participation decisions, thus they are more aware of and evaluate a larger range of possible attitudinal positions before making a behavioural decision (Celsi & Olson, 1988; Williams, et al., 1990; Ventatraman, 1988; Kerstetter & Kovich, 1997; Jamrozy, et al., 1996; Hammitt et al., 2004). Because of the specialized knowledge of highly involved individuals they are more susceptible to negative influences such as marginal snow conditions and are more likely to perceive factors such as climate change as a constraint or conflict than less involved individuals (Williams, et al., 1990; Hammitt et al., 2004). According to Social Judgment Theory, it is more difficult to persuade a highly involved individual of something in comparison to someone who is less involved. Therefore, if an individual who is highly involved in the activity of skiing has decided that marginal snow conditions are indeed present and that participation will not be worthwhile (i.e. they have experience skiing in better conditions and current conditions are not sufficient), it becomes very difficult to encourage participation (see Hammitt et al., 2004).

5.3.5 Place Loyalty Clusters

Clear place loyalty clusters were not established in this study, however evidence was found to suggest that commitment to the activity of skiing is stronger than loyalty to a particular ski area. This is seen when examining the mean dimension scores of place loyalty, evaluated through the PCI scale, which range from 2.7 to 3.7 compared to, mean commitment to activity scores, measured through the MIS scale (mean range of 3.0 - 4.1) (Table 22; also see Table 20).

Table 22: Mean loyalty scores (PCI dimensions)

PCI items (place loyalty)	Mean Score (n=1145)
Resistance to Change(items a & b)	3.3
Position Involvement(items c & d)	2.7
Volitional Choice (items e & f)	3.0
Informational Complexity (items g & h)	3.7

Previous research suggests that individuals who have reported high involvement in a particular activity also tend to report strong levels of psychological commitment and loyalty to a favored service provider (Gahwiler & Havitz, 1998; Iwasaki & Havitz, 2004). This may, or may not, be the case for respondents within this study as it was not possible to develop clearly delineated place loyalty clusters. However, statistical significance was found between activity involvement clusters (high, medium and low) and individual PCI loyalty scale items, thus providing some evidence for this relationship ($p<0.000 – 0.001$) (Table 23).

Table 23: Cross-tab of activity involvement clusters and place loyalty dimensions (PCI)

PCI loyalty dimensions[1]	High Activity Involvement (MIS)	Medium Activity Involvement (MIS)	Low Activity Involvement (MIS)
Resistance to Change (a) (x^2=173.2, df=12, p<0.000)	15	45	40
Resistance to Change (b) (x^2=209.3, df=8, p<0.000)	14	44	43
Position Involvement (c) (x^2=181.7, df=8, p<0.000)	17	44	38
Position Involvement (d) (x^2=270.8, df=8, p<0.000)	14	46	40
Volitional Choice (e) (x^2=94.3, df=8, p<0.000)	26	40	43
Volitional Choice (f) (x^2=25.7, df=8, p<0.001)	31	47	22
Informational Complexity (g) (x^2=130.5, df=8, p<0.000)	17	43	39
Informational Complexity (h) (x^2=252.4, df=10, p<0.000)	9	43	48

[1] letter in brackets refers to scale dimension on the skier survey (see Appendix 3)

Under future change conditions, the extent to which individuals are loyal to particular service providers will play a significant role in ski area sustainability. Ski area operators are expected to experience increased expenditures under warming scenarios and in order to offset the increasing cost of operation, managers will need to maintain a consistent source of revenue, which is mainly sustained through regular demand patterns. Maltzler et al., (2007) suggested that consumer spending behaviour is a crucial variable for the ski sector, further implying that economic sustainability can only be achieved by increasing either customer base or the average amount of per person spending. Scott & McBoyle (2007) examined climate change adaptation strategies for ski area service providers outlining that ski areas who develop non-ski related activities (i.e. snow tubing, swimming pools, bars) as well as retail opportunities, could significantly improve their ability to negotiate through future warming regimes without significant economic impact. This was evident during the marginal winter season of 1998-99 when temperatures in the US Northeast were 2.7°C (4°F) above average winter conditions (equivalent to a 2050s mid range climate change scenario). Revenue per skier visit was five dollars more that season than during an average climatic season (1961-90) meaning that despite decreased overall visitation because of poor snow conditions operating profits were not impacted. Similar to what has been suggested by Scott & McBoyle (2007) adaptations that were made by skiers that year included increased spending on food and beverage as well as retail (i.e. sports apparel, clothing, etc) (see Dawson et al., 2009). Whether this type of spending would occur in periods of prolonged marginal conditions is not clear.

5.4 Conclusion

Very few studies have examined the impact that climate change is expected to have on the demand-side of the ski tourism sector (see König, 1997; Behringer et al., 2000; Fukushima et al., 2002; Hamilton et al., 2007; Unbehaun et al., 2008; Shih et al., 2009). This study builds on the limited understanding of climate-induced behaviour change by examining the influence that commitment plays on climate-induced substitution behaviour. Commitment is thought to develop through repeat visitation, satisfaction during participation, and in the absence of conflict or constraint (Crawford & Godbey, 1987; Henderson, et al., 1988). Considering marginal snow conditions under future climate change scenarios represent a significant constraint for the ski tourism sector, the study of involvement and loyalty within this context seems particularly important.

The cluster analysis of activity involvement suggested that individuals exhibiting high levels of involvement (i.e. commitment to the activity of skiing) were more likely to change their skiing behaviour as a result of climate change than individuals with low levels of involvement. Although this finding may initially seem backwards considering that highly involved individual's rate skiing as a very important part of their lives and personal identities in comparison to less involved individuals, the findings are consistent with previous research examining general leisure behaivour (Sherif et al., 1965; Celsi & Olson, 1988; Williams, et al., 1990; Ventatraman, 1988; Kerstetter & Kovich, 1997; Jamrozy, et al., 1996; Hammitt et al., 2004). Highly involved individuals are generally very particular and highly susceptible to constraints and therefore are more easily influenced by change. Individuals with low levels of involvement generally exhibit a lower level of expectation and are therefore less influenced by change. They also participate in skiing for very different reasons than highly involved individuals, including the opportunity to spend time with friends and family or take part in après ski activities in comparison to the desire to ski in pristine conditions or terrain that challenges their skills.

It will be important for ski area managers to understand the variety of substitution tendencies and responsive behaviours expected from different types of people in order to develop and implement individualized and appropriate adaptation strategies. For example, despite the fact that highly involved skiers only make up 23% of the skier market, they tend to participate at a much higher frequency than less involved skiers (mean = 31 days/yr. vs. 6 days/yr.). This study, which examines the extent to which activity involvement and place loyalty influences climate-induced behaviour change, paints a more comprehensive portrait of possible future climate change impacts than was previously available. A greater understanding of these dynamics will allow ski area operators as well as communities that rely on the ski sector to implement more effective and sustainable adaptation strategies for reducing climate change vulnerability. Simultaneously, the research enhances theoretical knowledge of leisure-behaviour by infusing the role of climate and environmental conditions, which to date have rarely been considered in the tourism-recreation literature. Further research should be conducted examining activity involvement; particular effort should be made to understand highly involved individuals and what adaptation strategies could be employed to reduce their high behavioural substitution tendencies. The role of loyalty to place should also be examined with respect to substitution behaviour anticipated under future climate change scenarios. This study was unable to establish place loyalty clusters and as a result could not examine the construct in this context.

Chapter 6: Summary and Conclusions

This chapter begins by summarizing the significant findings of this study, first by discussing the impacts that climate change is expected to have on the supply-side of the US Northeast ski industry (objectives one and two), and second by discussing the projected demand-side impacts (objective three). This is followed by a brief evaluation of the methodologies employed in this study, including dialogue regarding the contrasting and complementary elements of the methodological findings. Study conclusions are provided as well as suggestions for future research.

6.1 Summary of Results

In the absence of planning or adaptation, the international ski sector is likely to experience severe impacts due to projected climate change conditions. Past experience and previous research has identified the effectiveness of adaptation strategies within the ski sector, including snowmaking, to reduce the negative consequences of marginal snow conditions and other climatic conditions expected under future change scenarios (see Hennessy et al., 2003; Scott, et al., 2003, 2005, 2006, 2008; Dawson et al., 2009a). The goal of this study was to examine climate change vulnerability (both supply-and demand-sides) for the US Northeast ski tourism sector in order to better understand how the regional marketplace, as a whole, is likely to change in response to projected climate change. Understanding how the US Northeast ski area marketplace may contract under climate change conditions, including how that ski area's competitors may fair under future conditions, and how demand-side behavioural response is likely to occur, allows operators and managers to develop and implement appropriate adaptation strategies that can help reduce the negative impacts of change while taking advantage of any opportunities. The three objectives of this study included:

1. *To use a climate change analogue to examine the influence that anomalously marginal snow conditions of the past have had on regional ski area operations (both supply-and demand-side);*

2. *To use modeling-based techniques to project future climate change impacts on ski areas operations (supply-side);*

3. *To use a skier survey to understand and determine likely behavioural responses to historic and expected supply-side impacts (demand-side).*

Several aims were also identified including to:

i. *examine the impact of unusually warm seasons of the past on season length, snowmaking hours, snowmaking power utilized, skier visits and operating profit;*
ii. *consider the effect of ski area elevation as a factor in vulnerability;*
iii. *project the impact of future climate change for, ski area season length, snowmaking requirements and probability of being operational during the economically important Christmas-New Year holiday period;*
iv. *examine contraction of the ski area marketplace based on economic sustainability;*
v. *examine how skiers have responded in the past, and intend to respond in the future, to marginal snow conditions;*
vi. *understand the role of substitution and specialization within specific behavioural responses;*
vii. *examine the role commitment (involvement) to the activity of skiing, and loyalty to ski areas, play in influencing behavioural responses.*

6.1.2 Climate Change Impacts on Supply

The majority of research attention given to the topic of climate change and ski tourism has examined the impacts of projected climate change on the supply-side of the sector (i.e. ski area operations). This supply-side focus has been warranted considering that an understanding of how the ski sector will fair under future change conditions is required in order to evaluate the demand-side response to the projected change in climate and in operational conditions. For example, if climate conditions were such that no ski areas could continue operation, the demand response would be irrelevant within that market, but may be significant to other markets if a transfer of demand was anticipated. Within this study, a variety of interacting supply-side impacts revealed a contraction of ski areas supply but not the complete elimination of the market. Many impacts are projected for the US Northeast region including, reductions in natural snowfall, increased snowmaking (amount, hours operated, fuel utilized), decreasing season length and decreasing probability that ski areas will be operational during the economically important Christmas-New Year holiday period, which collectively threaten economic sustainability through reduced revenues and increased operating expenses (see Box 1, page 53).

Future climate change scenarios for the US Northeast region project an overall reduction of natural snowfall (see Hayhoe et al., 2004, 2008; Frumhoff, et al., 2008). In this study, analysis of past snowfall during the anomalously marginal snow season, that is representative of a high emissions scenario for the 2040-69 time period, revealed a 40% decrease in natural snowfall. If a high emissions climate change scenario is realized (A1fi), 40% of the 103 modeled ski areas in the region will need to increase the amount of snow they produce by at least 50% by mid-century in order to make up for the projected decrease in natural snowfall. For the same type of climate conditions and timeframe, an analogue assessment of snowmaking hours and percent power required for the purpose of snowmaking displayed an increase of 75 and 37% respectively (A1B high emissions scenario).

Even with increased snowmaking efforts throughout the US Northeast, ski season length is still projected to decrease under future scenarios. Analogue assessments of both mid-range (B1) and high emissions (A1B) scenarios for the mid-century timeframe, revealed season length reductions of 3 and 11% respectively, totaling an average reduction of almost two weeks. Despite these reductions, analogue assessments reveal that the same ski areas will still be able to maintain 100-day seasons even under the high emissions scenario for the 2040-69 time period. Modeling-based projections, which are able to examine season length at an individual ski area scale, revealed a greater reduction in season length. For example, less than 30% of the 103 modeled ski areas were projected to maintain 100-day seasons during the 2040-69 time period under the high emissions scenario and less than 40% under the low emission scenario.

Over 20% of ski area revenue is generated during the Christmas-New Year holiday period in the US Northeast region, which occurs at the highly vulnerable beginning of the ski season (NSAA, 2007). Of the 103 ski areas modeled only 43% (B1 low emission) and 44% (A1fi high emissions) of ski areas were projected to maintain more than a 75% probability of being operational during the Christmas-New Year holiday periods for the 2010-39 timeframe. This projection decreased to 35% and 26% respectively during the 2040-69 time period and to 33% and 7% in the 2070-99 timeframe.

Considering the combination of increased snowmaking costs, decreased season lengths and lowered probability of being operational during key holiday periods, it is not surprising that US Northeast ski areas are expected to experience decreased profitability under future warming scenarios (see Scott et al. 2008; also see Box 1, page 53). However, the analogue assessment in this study revealed almost no change in operating profit (+2%) (as a percent of gross fixed assets - i.e. excluding depreciation and/or amortization) for the mid-range emissions scenario (B1) in the 2040-69 time period. The analogue season examined was the third consecutive season to experience average winter temperatures of +2.7°C (+4°F) above normal. Operating profit was not impacted during this season likely due to adaptation strategies and business decisions implemented by operators in the region who to some extent had learned to adapt to the two previous marginal seasons. For example, revenue per skier visit was $5 more per person during these marginal snow seasons than during a normal season reflecting increased revenue from food and beverage as well as general retail (NSAA, 1998; 2004). During the analogue season representative of a high emission scenario (2040-69), there was a -33% decrease in operating profit (% gfa). Revenue per skier visit was less than during average seasons (-US$2.08 per person) and marketing expenses were increased (+US$0.30 per person) likely reflecting efforts made to increase visitation despite marginal conditions (NSAA, 2002, 2004). These examples reiterate the importance of implementing adaptation strategies including retail opportunities, après ski events, and other activities, which as seen can greatly reduce the negative impacts of changing climatic conditions.

Regional vulnerability is clearly delineated between high elevation ski areas in the north and lower elevated ski areas in the south. Ski areas in the southern portion of the US Northeast including operations in Connecticut, Massachusetts and southern New York are projected to experience significant climatic challenges making it very difficult to maintain 100 day season lengths within the next two to three decades. Conversely, ski areas located in more northern latitudes including many higher elevation operations in Vermont, New Hampshire, Maine and northern New York are expected to be significantly less vulnerable to projected climatic changes and in some cases are projected to maintain at least 100 day seasons beyond the twenty-first century even under high emissions scenarios. Ski areas located in Vermont are expected to be the least vulnerable to climatic change with only one ski area in that state (i.e. Cochran) unable to maintain 100-day season length by the 2070-99 time period. Conversely, all ski areas modeled in Connecticut (i.e. Sundown, Mohawk, Woodbury, Southington and Powder ridge) drop below the 100-day season length threshold by the 2010-39 time period under all climate change emission scenarios

6.1.3 Climate Change Impacts on Demand

The importance of understanding climate change vulnerability for the demand-side of the ski sector is clear, considering how easily tourists can adapt their behaviour to climate variability through activity-based, spatially-based or temporally-based substitution. These planned and sometimes last minute adaptations are made with little effort on the part of the skier/snowboarder, especially in comparison to the difficulty and expense involved in structural adaptations currently being used or considered by ski areas managers (see Scott & McBoyle, 2007). This study focused on understanding climate-induced substitution behaviour by examining changes in skier frequency during historically marginal snow seasons and also through a skier survey. A profile of who engages in different types of substitution behaviour was developed through the skier survey, which included consideration of demographics, specialization, past experience, activity involvement and loyalty.

In this study, an overall increase in climate-induced substitution behaviour was revealed when comparing climate-induced behaviour change in the past with that anticipated for the future. The findings indicate that there is likely to be some degree of demand-side change under future climate change scenarios, however to a much lesser extent than projected in earlier studies by König (1998), Behringer et al., (2000) or Bürki (2002). Visitation to US Northeast ski areas only decreased by 11% and 12% during the analogue seasons in this study that are representative of a mid-range (B1) and high (A1B) emissions scenario respectively (2040-69 time period), which is much less significant in comparison to projected decreases of up to 75% seen in earlier studies (König, 1998; Behringer et al., 2000).

Through the survey employed in this study, climate-induced substitution patterns occurring during past ski seasons with marginal snow conditions (i.e. similar to 2001-02 and the start of 2006-07) were compared with intended behavioural change in response to marginal conditions in the future. This comparison revealed that a large proportion of survey respondents already engage in some sort of substitution behaviour during marginal seasons at present and in the past and as a result the net difference in projected behaviour change is not as significant as has been revealed in earlier studies (referenced above). Compared to how respondents reacted in the past, a one percent increase was revealed in individuals who would '*stop skiing for an entire season'*, a five percent decrease was evident in individuals who intend to 's*top skiing for part of the season'* and six percent fewer individuals plan to '*do something else*' instead of skiing. Just over 20% fewer individuals indicated that they would '*travel to another ski area in the US Northeast'* region to participate and just over 25% fewer would '*travel outside the region'*.

Theoretical constructs, from the leisure studies literature, were used to profile survey respondents in order to better understand which individuals more readily engage in different types of substitution behaviour in comparison to others. Understanding who reacts to marginal snow conditions, and in what way, can help ski area managers develop specific demand-side adaptation strategies that may help to reduce the negative impacts of future change. Individuals who were the most likely to engage in substitution behaviour in this study included those who were specialized in the sport of skiing (i.e. a lot of past experience, own equipment), those who rated themselves as having intermediate or expert skill levels, and those who were the most committed (i.e. involved) to the activity of skiing. Demographics did not play a role in distinguishing individual substitution tendencies.

These findings are directly congruent with past literature which suggests that individuals exhibiting higher levels of specialization and activity involvement have narrow ranges of acceptance and broad ranges of rejection relative to those who are less involved or less specialized. Highly involved individuals tend to seek out and therefore draw upon more information when making participation decisions, thus they are more aware of and evaluate a larger range of possible attitudinal positions before making a behavioural decision. Because of the specialized knowledge of highly involved individuals they are more susceptible to negative influences such as marginal snow conditions and are more likely to perceive factors such as climate change as a constraint or conflict than less involved individuals (Sherif, et al., 1965; Bryan, 1977, 1979; Celsi & Olson, 1988; Williams, et al., 1990; Ventatraman, 1988; Kerstetter & Kovich, 1997; Jamrozy, et al., 1996; Hammitt et al., 2004).

6.2 Evaluating and Comparing Methodologies

The findings of the three methodologies employed in this study (analogue, modeling and skier survey) are largely complementary, thus strengthening confidence in them and suggesting the approaches were reasonably successful in the goal of evaluating climate change vulnerability of the US Northeast ski sector. One incongruence within the study involved analysis of season length reduction using the analogue versus a modeling approach.

In order to directly compare season length findings between the regionally-based analogue study and the market-level modeling study, results of the modeling assessment (103 individual ski areas) had to be regionally aggregated. A list of ski areas that participated in the NSAA end of season report used in the analogue assessment was used to determine which ski areas should be included in a regional aggregation of modeled data; meaning that although this is a regionally-based assessment of aggregated projections it is based on data from the same individual ski areas (n=43).

The regionally-averaged 1961-90 season length baseline used in the modeling study was 132 days, which compares very well to 133 days reported for the two climatically average (for 1961-90) years in the analogue study. However, ski sim modeled projections for future time periods predict greater season length loss than was found in the analogue assessment. Under the modeled mid-range emissions scenario (B1) for the 2040-69 time period, which is directly comparable to the analogue study (2050s B1), season length declined to 116 days in comparison to the analogue projection of 128 days. For the high emissions scenario in the 2040-69 time period (A1fi), the ski season length was projected to decline to 108 days, which again was more than was observed in the 2040-69 high emissions analogue (A1B) where the season length was 118 days (-10 days).

One of the disadvantages of physically-based snow modeling techniques is the current inability to account for business/management decisions and adaptations (i.e. opening under even very marginal conditions because of staffing inflexibility to provide some level of skiing, perhaps only one or two runs, to guests staying in resort accommodations, development of non-snow-based activities, provision of retail activities etc.) (see Table 2, page 7 and 8), thereby tending to overestimate impacts. Although the ski sim approach does have adjustable parameters to account for some management decisions, including opening under a variety of snow depths, making snow at a variety of temperatures and closing if certain rain events occur, it is unable to account for on-the-spot decision making that is based on ski area demand, local weather conditions or other operational factors. The presence of this minor and yet explainable incongruence suggests that the use of multiple methods in a climate change vulnerability assessment should be promoted.

6.3 Study Synopsis

This study employed a systems-based approach in order to examine climate change vulnerability for the US Northeast ski sector (see Section 1.3 – also see Figure 2, page 15). This type of approach aims to establish greater understanding of complex eco-social problems, such as those seen within the tourism industry, by analyzing the behaviour of a system as a whole and also in its individual parts rather than simply examining separate components in isolation of each other. The impacts of climate change on ski area supply and ski area demand were evaluated including an evaluation of how changes in each would influence the overall system. Three main conclusions are drawn from the study including; 1) there is likely to be a northward contraction of ski areas under future climate change scenarios (supply-side), 2) skier demand is not likely to contract proportional to the decrease in supply resulting in a market-shift favouring the ski areas that are able to remain operational (demand-side response), and 3) all ski areas and nearby communities will need to adapt to future change regardless of whether they anticipate remaining viable under future climate change conditions (system-wide adaptation) (Box 2, also see Appendix 2).

Box 2: Projected Future of Ski Areas in the US Northeast

	Higher Elevation Ski Areas	Lower Elevation Ski Areas
North	-all ski areas remain operational -expected increase in skier demand -crowding of slopes, chalets, and parking lots -infrastructure development required -increased employment opportunities -real-estate development likely -resource shortages -recommend investment in renewable energy or alternative power -recommend development of other snow-based and non-snow based activities	-ski areas likely to cease operation by mid-century unless significant investments are made -business diversification strategies required -loss of demand to nearby ski areas located at higher elevation -ski areas may retain some demand -recommend catering supply to beginner skiers, families and individuals desiring a less commercial atmosphere -recommend development of non-snow based activities
Middle	-most ski areas remain operational -expected increased in skier demand -possible crowding issues -increased competition between viable ski areas in this area and in the northern region some infrastructure development required -some increase in employment opportunities -some real-estate development likely -investment in higher efficiency snowmaking required -recommended investment in renewable energy or alternative power -recommended development of other non-snow based activities (i.e. après ski, retail etc.)	-some ski areas remain operational -expected decrease in skier demand (i.e. shift towards higher elevation ski areas in the area or ski areas further north) -business diversification strategies required -recommended development of non-snow based activities -possible decrease in real-estate values in some locations -employment losses (downsizing) -snow-based retail opportunities continue to exist (i.e. catering to skiers traveling to viable ski areas)
South	-n/a	-all ski areas likely to cease operation by mid-century -significant investments and adoption of new business strategies required - diversification from snow-based businesses to non-snow businesses likely to occur -possible decrease in real-estate values in some locations -employment losses -snow-based retail opportunities continue to exist (i.e. catering to skiers traveling to viable ski areas)

6.3.1 Contraction of Ski Area Supply

Scott et al., (2008) indicated that determining where the ski industry might contract and which communities need to prepare for what type of future changes is an important priority for future research. Individual ski operators need to understand how their own ski-area may fair under future climatic conditions in comparison to others so that appropriate management decisions can be made. Results of this study suggest that there is likely to be a northward contraction of supply in the US Northeast, as some ski area operators become unable to afford the cost of adapting to the change in climate projected for the region. Differential vulnerability among ski areas revealed through both analogue and modeling-based assessments in this study suggest that small ski areas, located at low elevations, are the most likely to experience the greatest impact from future climatic change. Ski areas located at higher elevations are inherently at an advantage due to lower mean temperatures and a greater proporation of winter precipitation falling as snow. Ski areas situated at higher elevations experience fewer marginal natural snow conditions and are able to produce machine-made snow more often and at lower costs than lower lying ski areas (i.e. machine-made snow typically requires temperatures of 23°F (-5°C) or colder to be produced effeciently – Scott et al. 2003).

In this study, ski areas located in the more elevated regions of Vermont, New Hampshire, Maine and Northeastern New York were projected to remain operational into the late 21st century even under the highest emission scenario. Conversely, ski areas located in areas of low elevation including Connecticut, Massachusetts and Southern New York are projected to experience significant difficulties remaining economically viable as early as the 2010-39 time period, and as a result are projected to cease operation (see Appendix 2). However, strategic adaptation plans can help to significantly reduce the vulnerability of individual ski areas to changing climate conditions. For example, Jiminy Peak which is located in a relatively vulnerable, low elevation, area in Massachusetts, has invested in new higher efficient snowmaking technology (LP3) that includes a heat-recapture system used to warm three nearby buildings. In addition, a wind turbine has been installed to offset their increasing energy needs which currently total 7,500,000kWh a year. Savings that Jiminy Peak currently receives through these two adaptations alone total 19,671,000 kWh a year, representing just less than 30% of their annual energy budget (Jiminy Peak, 2009).

Without significant investment, such as that made by Jiminy Peak, the projected contraction of the ski sector due to ski area closures in this study could greatly increase driving distances between major regional urban centres and operating ski areas. For example, driving distance between the city of Buffalo, NY (population 272, 632) and the closest operating ski area in the US Northeast is projected to increase by almost five and a half hours in the 2040-69 future time period. Driving distance is expected to increase by up to three hours between the major city of New York, NY (population 8,274,527) and an operating ski area, and by just over two hours for residents of Boston, MA (population 599,351) (Jiminy Peak, 2009). The demand-side implications of increased driving times are unclear; however possible responses could include an increase in multi-day ski vacations (i.e. vs. day trips) or a reduction in skier visits (i.e. activity substitution).

The economic implications of climate change cannot be fully assessed due to the proprietary nature of business information. However, it is clear that the implications will not just affect the ski tourism sector in isolation but will likely play a rather significant role in the future of individuals and nearby communities that heavily rely on the sector. The US National Assessment (2003) indicated that between Vermont and New Hampshire alone, over 15,000 people are directly employed by the ski industry and another 34,500 are indirectly employed to provide goods and services to skiers. In addition, over US$4.6 billion annually is contributed to the US Northeast regional economy through snow-based activities (not including snowmobiling) (Southwick Associates, 2006).

6.3.2 Demand-side Market Response

The extent and rate with which skier demand is impacted as a direct influence of climate change will play a significant role in the vulnerability of the ski sector and on the type of adaptation strategies that will need to be implemented by operators and communities. Projected changes in the length of ski tourism seasons are likely to reveal considerable implications for the competitive relationships between destinations and therefore the profitability of certain tourism enterprises. For example, marginal snow conditions at one resort may encourage skiers to travel to another local ski area where conditions are more favorable (see Carmichael, 1996; König, 1998; Behringer et al., 2000; Bürki, 2002; Elgin & Moeltner 2004; Hamilton et al., 2007; Unbehaun et al., 2008).

Findings from this study reiterate the fact that poor snow conditions affect the frequency with which individuals participate in skiing activities. However, the extent to which individuals in this study intend to change their skiing behaviour in response to expectedly poor conditions in the future was not significantly greater than the extent to which they already change their skiing habits when current conditions are poor, suggesting that the future response to climate change is likely to be similar to that which has been observed during marginal snow conditions of the past. Historic seasons with marginal snow conditions influenced a reduction in skier visitation by 11% and during the particularly poor season of 2001 a reduction in operating profit of 32%.

The most commonly stated behavioural response by skiers in the region involved some sort of spatial substitution whereby individuals would travel to another ski area where they could continue to participate in the activity of skiing. Analysis of the demand-side response suggests that there is likely to be demand-side market shift favouring those ski areas that are still operating under future climate change scenarios, versus a significant reduction in overall skier demand. This projection is further supported by the high involvement scores revealed among skiers in the US Northeast region. In increasingly saturated (i.e. crowded) marketplaces (i.e. such as that projected for the US Northeast ski sector under future climate change scenarios), the success of a destination depends strongly on tourist motivation, customer satisfaction and loyalty (Yoon & Uysal, 2005). However, in this study, individuals with high involvement scores were also found to exhibit the highest substitution tendencies and are therefore were the most likely to change their behaviour under expected future marginal snow conditions. Although it is evident that there is likely to be a change in future skier demand due to changing climate conditions, the supply-side impacts that have been projected Scott et al., (2008), Dawson et al., (2009a – Chapter 2) and Dawson & Scott (Chapter 3) are likely to be disproportionally higher. Thus it is likely that there will be a net transfer of demand throughout the remaining marketplace under future climate change conditions.

6.3.3 Community and Operator Adaptation under Future Climate Change Conditions

Understanding that there is likely to be a contraction of ski area supply in the US Northeast region, combined with a disproportionally lower reduction in demand, will require the tourism industry as well as local communities to develop and implement appropriate and site-specific adaptation strategies to both reduce the negative impacts of change, while taking advantage of any residual opportunities. Managers of ski areas in the US Northeast can use the projections developed in this study to negotiate through the 'climate change management decision making flowchart' presented in Figure 1 to help evaluate future business decisions. For example, some ski operators and nearby communities will need to prepare for increasing pressure due to the anticipated geographic shift in market demand, while others will need to develop economic diversification plans in order to offset the loss of local ski areas.

The ski area marketplace that remains, despite the impact of future climate change, may need to prepare for development pressures (e.g. water use for snowmaking, real estate development, slope expansion, congestion) associated with the concentration of ski tourism in fewer areas. Increasingly crowded slopes, ski chalets and lift lines are likely to result under projected future conditions. Transportation infrastructure, including ski area parking lots and roadways may require expansion with increased visitation and congestion. Community-based impacts could include increasing real-estate values, so much that local residents may no longer be able to afford to live nearby, as well as increased pressure on local services and environmental resources.

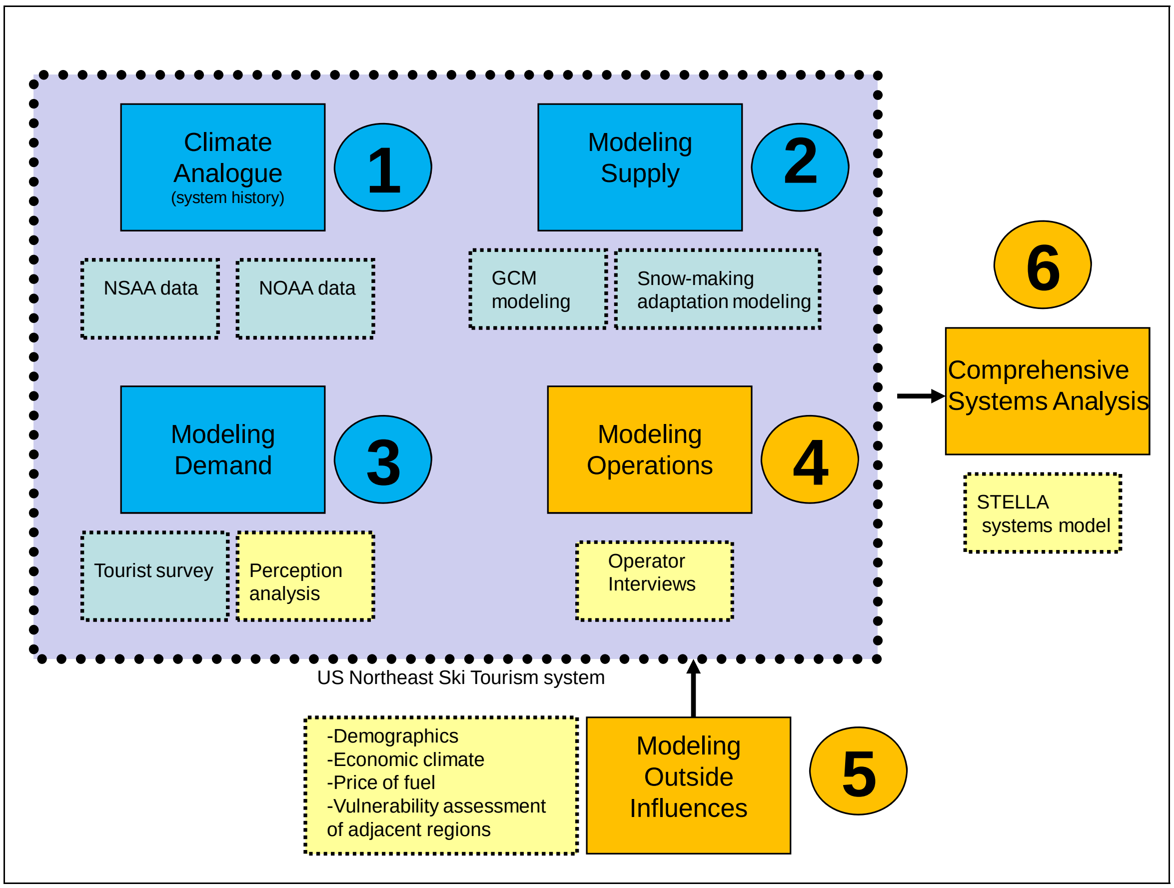
The more vulnerable ski areas in the region will, at varying points, need to determine if they should invest heavily in adaptations that will aid in continuation of a snow-based business at least in the short to medium term (i.e. high efficiency snowmaking, renewable energy production), if they should invest in adapting and evolving into a multi-season destination (i.e. four-season resort, spa, conference centre), or if they ultimately need to terminate their business altogether.

6.4 Future Research

This is the first known study to examine climate change vulnerability for an entire regional ski marketplace, by examining both supply- and demand-side impacts within a single geographical region. Climate change and tourism research has traditionally examined either the supply-side or the demand-side impacts for a particular sector and has generally focused on isolated areas versus analyzing an entire regional sector. Future research examining the impact that climate change has on the ski sector, or on another tourism sector, should consider the benefits of examining tourism-related problems from this sort of systems-based perspective (i.e. analysis of demand and supply), considering the strong relationship between the elements of supply and demand and the competitive relationship between businesses within a regional area.

It is very difficult to understand and respond to complex problems such as climate change, which manifest at a variety of scales (i.e. global, regional and local), and in a variety of ways, and as a result, problems tend to be addressed linearly and in piecemeal and manageable sections instead of as a (whole) system. However, the IPCC (2007) has recommended integrated approaches to manage future climate change and related socio-economic impacts within all major sectors. Patterson et al., (2006), Becken & Hay (2007) and Dawson et al., (2007) further outline the need to better incorporate integrated systems-based approaches specifically when examining the issue of climate change within the tourism-recreation sector. Further support for a systems approach in general tourism research has been expressed by a variety of individuals (i.e. Leiper ,1990; McKercher, 1999; Russell & Faulkner, 1999; Faulkner & Russell, 2003a, b; Patterson et al., 2003; Papatheodorou, 2004; Farrell & Twining-Ward, 2004; Walker et al., 2005; Woodside et al., 2006).

This study included the first three steps of a full systems analysis of climate change vulnerability for the US Northeast ski sector (Figure 16 – steps 1-3). Three additional steps are recommended (Figure 17 – steps 4-6).



<u>Note:</u> blue boxes represent completed research, yellow boxes represent recommended future research

Figure17: A systems-based approach to examine climate change vulnerability of the US Northeast ski sector

Step four involves modeling ski area operations. Operator interviews could be conducted with a selection of ski area managers in the US Northeast to discuss decision making patterns and operational protocols used when dealing with marginal snow conditions. Additional knowledge about how mangers currently deal with marginal snow conditions, including those seen in 2001-02 and during the beginning of the season in 2006-07 could help to refine supply-side modeling techniques through the inclusion of additional business-side variables; a better understanding of economic thresholds including the role that climate plays vs. other factors in operational decision-making could be very valuable. Although these inclusions would not completely eliminate the limitation that modeling-based approaches cannot adequately incorporate business-related decisions due to the complexity and subjectivity involved, it could help to reduce it. New insight into intended climate change adaptation strategies that have been developed, or could be developed should also be discussed, as well as the usefulness and potential refinement of the 'climate change decision making flowchart' developed in this study (Figure 4, p. 47).

Step five involves the consideration of non-climatic influences of change (i.e. demographics, economy, social trends etc.). The need to better integrate socio-economic scenarios in climate change impacts and adaptations research has been clearly acknowledged (Berkhout et al., 2001; Lorenzoni et al., 2000; Shackley & Deanwood, 2003; IPCC, 2007). When specifically discussing a systems approach that is appropriate for examining climate change vulnerability for the tourism sector, Dawson et al., (2009b) stated that,

> *"A systems perspective must also include acknowledgement of non-climatic influences including other physical barriers, institutional structures, technological developments, government regulations/policies, socio-economic circumstances, demographics, culture/religion, past experience, and tourism activity itself" (p.8).*

Criticism of past climate change and tourism research can be made based on its tendency to conduct studies using 'business as usual' scenarios, which reflect an unrealistic static social system (i.e. exclusion of socio-economic and demographic change). In the future, demographic change and the temporary decline in global economies could greatly impact the make-up of regional ski area demand. The fluctuating price of fuel and energy could also play an influencing role considering the longer distances individuals are projected to travel in the future when many ski areas currently located close to major urban centers cease operation (see Chapter 3). The increased cost to travel outside of the US Northeast region may facilitate a "ski local" trend that could advantage viable ski areas close to large urban centres.

Step six suggests that the full systems analysis of climate change vulnerability for the US Northeast ski sector be modeled using STELLA systems modeling software. STELLA is considered a very powerful tool as it is easy-to-learn and also has an 'authoring' feature that enables the development of models “for use by others who are uninterested in, or ignorant, of the underlying details of the model” (Hannon & Ruth, 2001, p.12). A market vulnerability model has utility for both researchers and ski area operators interested in understanding specific vulnerabilities or adaptation options available for particular ski areas or regional marketplaces. Knowledge from this study including results from the analogue, modeling and skier survey could be integrated into the STELLA model, as well as findings from the recommended future research. Basic variables in the model could include but are not limited to, demand-side components, supply-side components, economic conditions, adaptation strategies and external influencing factors. Variables could be changed based on specific business information and the influence of all interacting factors could be analyzed and different adaptation strategies tested.

Additional areas for future research, which could be included in the systems analysis involved further investigation and consideration of the role that behavioural psychology plays in both influencing and understanding demand-side substitution behaviour. Other demand-side studies could include examining how far individuals are willing to travel in order to participate in the activity of skiing therefore further elucidating the extent to which particular ski areas are vulnerable considering their distance from major urban markets. Finally, an investigation of exactly what climatic conditions are considered ideal for skiing participation should be considered as well as thresholds examined with which could determine participation or non-participation. Understanding these factors could help develop an understanding of how the future demographic of skiers may develop if existing skiers are or are not willing to travel longer distances to ski. It will also shed light on the currently unanswered question; if new skiers are not exposed to a skiing culture will they take up the sport of skiing at all? Many smaller ski areas located in the highly vulnerable states Connecticut and Massachusetts act as ‘nursery hills’ to the larger ski resorts located further north. Currently, individuals from Boston and New York city are exposed to skiing and learn to ski at these smaller local resorts. If a skiing culture does not exist within a 500km radius of these major centers it is possible that fewer individuals will take up the activity, however this question remains unexamined.

6.5 Concluding Remarks

Over 10 years ago Wall (1998) stated that, “*Although the implications [of climate change] are likely to be profound [for the tourism sector], very few researchers have begun to formulate relevant questions, let along develop methodologies which will understand the nature and magnitude* *of challenges that lie ahead*” (p.614). Since this statement was made over a decade ago, research examining climate change within the tourism sector has developed rapidly (see Scott, 2005) to include consideration of the impact that climate change is likely to have on the industry (i.e. impacts and adaptation) and the impact that the tourism sector is likely to have on climate change (i.e. through release of GHGs – mitigation) (see Paterson et al., 2006). Many important research questions have been asked, and although there are many more that require analysis, the sector has now developed a useful foundation of research. However, as suggested by Wall (1998), and likely due to its relative infancy in comparison to other fields of research, there still remains an absence of comparable and sometimes appropriate methodological approaches within the climate change and tourism literature.

The lack of comparability is clearly evident within studies examining climate change vulnerability for the ski tourism sector. Impact analysis of ski areas around the globe has been conducted using a variety of different techniques, and as pointed out by Scott et al., (2003) many studies likely overestimate the possible impacts by neglecting to consider important adaptation strategies routinely used by the ski industry (snowmaking). Shaw & Loomis (2008) further indicated that approaches used to examine climate change within the ski tourism sector tend to focus on impacts for the supply-side in isolation from the influence that demand could have on net vulnerability. In direct response to these limitations, this study employed a systems-based approach to examine climate change vulnerability for the ski tourism sector.

Despite there being historic mention and discussion of the usefulness of a systems approach for tourism management, to date there remains an absence of studies that have actually applied the approach. This is likely because a systems-based approach requires a significant time commitment and availability of multiple resources. Because a full systems study was beyond the scope of this study, only the initial steps were completed including, an analysis of historic responses to climatic conditions (see Chapter 2), an evaluation of projected supply-side impacts (see Chapter 3), and the influence that supply-side changes may have on the demand response (see Chapters 4 and 5).

This is the first known study to examine climate change vulnerability for both supply and demand for an entire regional ski marketplace. Understanding the differential impacts (both supply and demand) expected throughout the US Northeast region could be useful for ski area managers trying to develop and implement appropriate planning and policy. Planning for climate change is currently very difficult considering the lack of comprehensive understanding of possible future impacts. Knowledge developed from this study could be used by operators to negotiate through the ‘Management Decision Making Flowchart’. It will be necessary for mangers to integrate additional proprietary business information, which is not available to researchers, into the flowchart when assessing local vulnerability.

The study also contributes to the climate change and tourism literature which, to date, has neglected to consider the value of theoretical constructs that are widely available within the behavioural psychology and recreation-leisure literatures. This is the first known study to infuse well-established theoretical constructs such as, specialization, constraints, substitution, activity-involvement and place-loyalty, into an analysis of climate change vulnerability. This application has advanced our currently limited understanding of the impact that climate change is likely to inflict on skier demand.

Additional steps required for the completion of a systems-based analysis of climate change vulnerability for the US Northeast ski sector could include operator interviews and analysis of outside influences of change (i.e. demographics, socio-economics). These steps will be important in determining what planning and policy options are appropriate for ski areas in the region. Climate change is only one of many factors that are likely to impact the regional ski area marketplace. Other issues such as federal and state tourism policy, economic recessions, increasing costs associated with travel, competition with other tourism destinations, and social trends that favour particular experiences are likely to prove equally, or in some cases even more, important as the direct impacts of climate change. Nevertheless, the significant impacts projected in this study suggest that climate change is a necessary consideration in all aspects of planning and development for the Northeast US.

Appendices

1. State Level Ski Area Modeling Results

1.1 Modeled results for ski areas in Connecticut

Season Length with Snowmaking (% change and # of days) – Connecticut

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	% change	% change	% change	#	% change	% change	% change
Mohawk	75	-29	-52	-72	76	-32	-38	-52
Southington	62	-34	-60	-79	62	-37	-47	-58
Powder Ridge	64	-33	-58	-78	65	-36	-45	-56
Sundown	69	-32	-56	-76	69	-34	-41	-55
Woodbury	65	-31	-57	-77	66	-35	-43	-56
	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	(days)	(days)	(days)	#	(days)	(days)	(days)
Mohawk	75	54	36	21	76	52	48	37
Southington	62	41	25	13	62	39	34	27
Powder Ridge	64	43	27	14	65	41	36	29
Sundown	69	47	30	17	69	45	41	31
Woodbury	65	45	28	15	66	42	38	30

Snowmaking Requirements – Connecticut

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	cm	% change	% change	% change	cm	% change	% change	% change
Mohawk	242	3	3	-18	245	7	12	-3
Southington	243	0	-6	-34	244	0	4	-14
Powder Ridge	243	1	-5	-31	244	1	6	-12
Sundown	242	2	-3	-26	243	3	9	-9
Woodbury	243	2	0	-29	245	2	7	-12

Probability of being operational during key holiday periods – Connecticut

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	#	#	#	#	#	#	#
Mohawk	47	13	9	1	46	14	16	11
Southington	29	7	3	0	31	7	7	6
Powder Ridge	32	8	6	0	32	7	7	9
Sundown	34	10	6	0	34	8	10	10
Woodbury	32	8	6	0	31	8	7	9

1.2 Modeled results for ski areas in Maine

Season Length with snowmaking (% change and # of days) – Maine

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	% change	% change	% change	#	% change	% change	% change
Big Rock	161	-9	-15	-29	162	-8	-10	-14
Big Squaw	178	-3	-7	-17	178	2	-3	-5
Eaton	146	-10	-18	-33	148	-10	-10	-16
Mt. Jefferson	151	-10	-18	-32	151	-10	-11	-16
Saddleback	179	-1	-5	-15	179	-1	-2	-3
Sugarloaf	178	-3	-18	-17	178	-2	-3	-5
Titcomb	151	-10	-18	-32	152	-10	-11	-16
Black	116	-16	-29	-50	116	-16	-16	-28
Camden	93	-19	-35	-61	92	-17	-19	-34
Hermon	87	-22	-40	-66	85	-19	-23	-37
Lost Valley	89	-22	-39	-65	87	-18	-22	-36
Mt. Abram	111	-15	-28	-51	112	-16	-15	-29
Shawnee	106	-17	-30	-55	107	-17	-17	-30
Sunday River	123	-14	-27	-46	124	-15	-15	-26
	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	(days)	(days)	(days)	#	(days)	(days)	(days)
Big Rock	161	147	136	115	162	149	146	139
Big Squaw	178	174	166	147	178	182	173	170
Eaton	146	132	120	99	148	133	133	124
Mt. Jefferson	151	136	124	102	151	137	135	127
Saddleback	179	176	169	152	179	177	176	173
Sugarloaf	178	174	146	147	178	175	173	170
Titcomb	151	136	124	103	152	137	135	127
Black	116	97	83	58	116	97	98	83
Camden	93	75	60	36	92	76	74	61
Hermon	87	69	53	30	85	68	66	54
Lost Valley	89	70	55	32	87	71	68	56
Mt. Abram	111	94	80	54	112	95	95	80
Shawnee	106	88	74	49	107	89	89	75
Sunday River	123	106	90	67	124	106	105	92

Snowmaking Requirements – Maine

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	cm	% change	% change	% change	cm	% change	% change	% change
Big Rock	82	31	66	116	77	36	37	55
Big Squaw	22	90	230	367	20	81	166	196
Eaton	105	28	57	20	102	27	29	43
Mt. Jefferson	101	28	59	102	99	26	27	42
Saddleback	15	109	302	526	15	90	186	215
Sugarloaf	22	90	230	366	20	81	166	194
Titcomb	99	28	59	103	98	27	27	42
Black	155	24	46	63	163	24	24	34
Camden	187	22	38	35	201	20	21	22
Hermon	198	19	32	23	212	18	19	16
Lost Valley	196	19	33	25	210	18	18	17
Mt. Abram	160	25	46	62	169	24	25	32
Shawnee	167	23	43	54	179	21	24	28
Sunday River	144	26	49	74	154	22	20	34

Probability of being operational during key holiday periods – Maine

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	#	#	#	#	#	#	#
Big Rock	98	98	89	74	99	96	78	92
Big Squaw	99	99	97	90	99	98	97	97
Eaton	98	94	79	61	97	92	88	87
Mt. Jefferson	98	97	84	64	98	92	89	90
Saddleback	99	100	97	93	99	100	97	97
Sugarloaf	99	99	97	90	99	98	97	97
Titcomb	98	97	84	65	98	92	90	90
Black	78	55	29	16	78	51	54	48
Camden	71	29	15	4	63	31	38	24
Hermon	62	26	10	1	55	24	29	20
Lost Valley	64	26	10	2	56	26	30	22
Mt. Abram	76	49	28	15	76	49	51	45
Shawnee	75	45	24	9	73	44	44	39
Sunday River	81	62	36	22	81	61	60	54

1.3 Modeled results for ski areas in Massachusetts

Season Length with snowmaking (% change and # days) – Massachusetts

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	% change	% change	% change	#	% change	% change	% change
Berkshire	109	-18	-29	-48	110	-14	-23	-36
Blandford	104	-19	-31	-50	105	-16	-24	-37
Blue Hills	96	-21	-34	-54	96	-18	-28	-40
Jiminy Peak	115	-16	-28	-45	116	-13	-22	-34
Otis Ridge	108	-17	-29	-48	108	-14	-23	-36
Butternut	108	-18	-30	-48	109	-15	-23	-36
Bousquet	96	-26	-40	-63	93	-22	-32	-45
Nashoba	89	-24	-40	-64	89	-22	-33	-46
Pine Ridge	102	-13	-27	-48	108	-16	-24	-37
Bradford	113	-14	-26	-47	116	-14	-21	-35
Ski Ward	96	-29	-43	-67	89	-22	-34	-46
Waschusett	100	-13	-27	-49	107	-17	-25	-38
	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	(days)	(days)	(days)	#	(days)	(days)	(days)
Berkshire	109	90	77	57	110	95	85	71
Blandford	104	85	72	53	105	88	79	66
Blue Hills	96	76	64	44	96	78	69	57
Jiminy Peak	115	96	83	63	116	101	91	77
Otis Ridge	108	89	76	56	108	93	83	69
Butternut	108	89	76	56	109	93	84	70
Bousquet	96	71	58	36	93	73	63	51
Nashoba	89	68	54	33	89	69	59	48
Pine Ridge	102	88	74	52	108	91	82	68
Bradford	113	97	83	60	116	100	91	75
Ski Ward	96	68	54	33	89	69	59	48
Waschusett	100	87	74	51	107	89	80	66

Snowmaking Requirements – Massachusetts

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	cm	% change	% change	% change	cm	% change	% change	% change
Berkshire	207	19	28	23	209	17	21	22
Blandford	215	18	27	18	218	15	20	20
Blue Hills	227	13	22	10	230	13	20	15
Jiminy Peak	196	21	30	28	197	19	22	27
Otis Ridge	211	19	27	21	214	16	20	21
Butternut	207	19	28	22	210	17	20	21
Bousquet	241	13	27	10	243	16	23	13
Nashoba	245	12	24	7	247	15	21	11
Pine Ridge	216	22	34	29	214	23	28	26
Bradford	205	24	36	37	205	23	28	30
Ski Ward	247	12	24	7	248	15	21	11
Waschusett	221	20	33	26	221	22	27	24

Probability of being operational during key holiday periods – Massachusetts

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	#	#	#	#	#	#	#
Berkshire	75	46	36	17	75	60	53	36
Blandford	73	39	27	14	74	51	52	30
Blue Hills	62	31	24	10	62	37	40	25
Jiminy Peak	77	48	40	22	77	69	63	39
Otis Ridge	75	46	31	17	75	56	53	32
Butternut	75	46	31	17	75	58	53	32
Bousquet	57	30	10	3	59	30	30	21
Nashoba	53	28	8	2	54	26	26	16
Pine Ridge	71	42	27	13	72	59	52	36
Bradford	72	49	39	20	73	62	58	46
Ski Ward	53	24	8	2	54	25	25	16
Waschusett	69	42	23	11	72	56	43	33

1.4 Modeled results for ski areas in New Hampshire

Season Length with snowmaking (% change and # of days) – New Hampshire

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	% change	% change	% change	#	% change	% change	% change
Black	80	-11	-22	-38	149	-12	-17	-24
Bretton Woods	121	-7	-15	-28	154	-9	-12	-17
Cannon	134	-4	-10	-22	169	-6	-8	-12
Cranmore	76	-11	-22	-38	164	-6	-8	-12
King Pine	59	-12	-24	-41	143	-12	-13	-20
Loon	111	-8	-17	-31	145	-11	-13	-19
The Balsams	118	-8	-15	-29	163	-7	-10	-15
Waterville	133	-4	-11	-21	168	-6	-8	-11
Wildcat	133	-4	-11	-21	173	-4	-6	-8
Attash	18	-14	-28	-45	155	-8	-10	-15
Crotched	18	-15	-28	-45	121	-14	-17	-28
Dartmouth	17	-14	-28	-45	122	-14	-16	-28
Gunstock	20	-14	-27	-44	122	-14	-16	-27
Sunapee	31	-12	-24	-41	127	-13	-15	-25
Pats Peak	12	-17	-30	-50	126	-13	-16	-25
Ragged	21	-14	-27	-44	115	-15	-16	-28
Tenney	17	-15	-28	-45	124	-14	-16	-27
Whaleback	17	-15	-28	-45	121	-14	-17	-28
	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	(days)	(days)	(days)	#	(days)	(days)	(days)
Black	147	138	123	92	148	131	128	119
Bretton Woods	165	158	146	119	167	157	152	143
Cannon	173	153	142	135	174	168	164	161
Cranmore	144	126	110	89	146	130	127	118
King Pine	136	129	112	80	137	120	118	108
Loon	161	149	136	111	162	149	146	137
The Balsams	164	157	144	117	166	155	151	143
Waterville	173	165	154	136	173	167	163	160
Wildcat	173	143	131	136	173	167	163	160
Attash	121	103	87	67	122	105	102	88
Crotched	121	104	87	66	121	104	101	87
Dartmouth	121	105	88	67	122	105	102	88
Gunstock	124	109	93	69	124	107	105	91
Sunapee	132	109	94	78	132	117	114	102
Pats Peak	111	97	81	56	111	93	91	78
Ragged	124	106	90	70	125	108	106	92
Tenney	120	103	87	66	121	104	100	88
Whaleback	120	108	94	66	121	104	100	88

Snowmaking Requirements – New Hampshire

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	cm	% change	% change	% change	cm	% change	% change	% change
Black	99	36	69	88	97	28	32	50
Bretton Woods	64	44	69	127	61	31	47	64
Cannon	42	36	102	178	38	41	84	94
Cranmore	101	36	67	102	98	29	33	52
King Pine	117	37	65	90	114	28	31	53
Loon	74	36	70	122	72	30	39	56
The Balsams	67	32	69	125	64	31	45	63
Waterville	45	35	94	161	41	37	76	88
Wildcat	45	35	94	161	41	37	76	88
Attash	161	26	50	49	168	27	29	31
Crotched	163	25	48	46	171	26	29	30
Dartmouth	162	27	49	49	169	27	29	31
Gunstock	155	27	50	51	163	27	31	34
Sunapee	143	29	54	60	147	29	31	40
Pats Peak	177	23	43	36	187	24	24	25
Ragged	155	27	51	52	162	27	30	35
Tenney	160	26	49	49	168	27	29	31
Whaleback	160	26	49	49	168	27	29	31

Probability of being operational during key holiday periods – New Hampshire

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	#	#	#	#	#	#	#	#
Black	85	65	58	38	87	76	74	63
Bretton Woods	92	84	71	63	93	89	84	83
Cannon	96	91	79	69	97	93	86	89
Cranmore	84	65	56	38	87	77	73	61
King Pine	79	59	51	29	83	71	68	56
Loon	92	82	70	54	91	87	84	80
The Balsams	92	83	71	61	92	89	84	83
Waterville	96	91	78	70	97	92	86	89
Wildcat	96	91	78	70	97	92	86	89
Attash	85	59	42	25	81	70	65	53
Crotched	81	59	41	23	82	71	66	53
Dartmouth	85	59	42	25	82	70	65	53
Gunstock	85	61	44	25	83	71	70	54
Sunapee	90	72	55	33	91	76	76	65
Pats Peak	77	51	32	17	75	61	58	36
Ragged	85	62	46	25	83	72	70	55
Tenney	85	59	41	25	82	70	65	52
Whaleback	85	59	41	25	82	70	65	52

1.5 Modeled results for ski areas in New York

Season Length with snowmaking (% change and # of days) – New York

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	% change	% change	% change	#	% change	% change	% change
Dry Hill	118	-13	-23	-42	119	-11	-15	-24
Gore	146	-10	-20	-35	147	-10	-12	-19
McCauley	148	-10	-19	-34	142	-4	-8	-13
Hickory	129	-12	-22	-39	129	-11	-12	-21
Oak	151	-9	-18	-33	152	-9	-12	-17
Royal	141	-11	-20	-36	142	-11	-13	-20
Snow Ridge	129	-11	-21	-39	130	-11	-12	-21
West	125	-13	-23	-41	125	-11	-14	-23
Whiteface	153	-8	-17	-32	154	-8	-12	-16
Willard	124	-13	-34	-41	128	-14	-16	-24
Brantling	92	-28	-46	-68	83	-26	-29	-45
Bristol	96	-18	-33	-55	98	-23	-27	-37
Cockaigne	95	-18	-33	-55	96	-23	-22	-37
Four Seasons	62	30	4	-43	80	-26	-31	-46
Greek Peak	96	-18	-33	-55	98	-23	-22	-37
Holiday Vally	97	-18	-33	-54	99	-22	-21	-37
Peek'n Peak	92	-20	-34	-58	94	-23	-23	-39
Song	94	-18	-34	-56	96	-23	-22	-38
Swain	94	-18	-34	-56	96	-23	-22	-38
Toggenburg	96	-18	-33	-55	98	-23	-27	-37
Holimont	89	-20	-35	-59	91	-25	-24	-37
Kissing Bridge	92	-19	-34	-57	94	-24	-23	-39
Labrador	93	-19	-34	-57	94	-24	-23	-39
Woods	88	-20	-21	-60	90	-24	-25	-41
Belleayre	106	-18	-29	-50	106	-15	-16	-26
Bobcat	131	-13	-23	-39	131	-11	-14	-21
Catamount	90	-21	-34	-58	90	-19	-20	-34
Cortina	122	-13	-25	-41	122	-12	-14	-23
Holiday Mountain	83	-23	-39	-64	83	-22	-23	-40
Mt. Peter	90	-21	-34	-58	90	-19	-20	-34
Plattekill	105	-17	-29	-50	105	-16	-17	-28
Sawsill	82	-23	-40	-65	82	-22	-24	-39
Sterling	93	-20	-33	-55	93	-18	-19	-32
Titus	83	-22	-38	-63	83	-21	-24	-40
Hunter	103	-17	-29	-51	103	-16	-17	-30
Windham	118	-13	-25	-43	118	-12	-16	-24

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	#	(days)	(days)	(days)	#	(days)	(days)	(days)
Dry Hill	118	103	90	68	119	105	101	91
Gore	146	132	117	95	147	132	129	119
McCauley	148	134	120	98	142	136	131	123
Hickory	129	113	101	78	129	116	113	102
Oak	151	137	124	101	152	139	133	126
Royal	141	125	112	90	142	126	124	114
Snow Ridge	129	115	102	80	130	116	114	103
West	125	108	96	74	125	111	107	97
Whiteface	153	140	127	105	154	142	136	129
Willard	124	108	82	73	128	110	107	97
Brantling	92	65	50	29	83	62	60	46
Bristol	96	79	64	44	98	76	72	62
Cockaigne	95	78	63	43	96	74	76	61
Four Seasons	62	62	46	26	80	59	56	43
Greek Peak	96	79	64	44	98	76	77	62
Holiday Vally	97	80	65	44	99	77	78	63
Peek'n Peak	92	74	61	39	94	72	72	57
Song	94	77	62	41	96	73	75	60
Swain	94	77	62	41	96	73	75	60
Toggenburg	96	79	64	44	98	76	72	62
Holimont	89	72	58	37	91	69	70	58
Kissing Bridge	92	74	61	39	94	71	72	57
Labrador	93	75	61	40	94	72	73	58
Woods	88	70	70	36	90	68	68	54
Belleayre	106	87	75	53	106	90	89	78
Bobcat	131	114	100	80	131	116	113	103
Catamount	90	71	59	38	90	73	73	59
Cortina	122	107	92	72	122	108	104	94
Holiday Mountain	83	64	50	30	83	65	64	50
Mt. Peter	90	71	59	38	90	73	73	59
Plattekill	105	87	74	52	105	88	87	75
Sawsill	82	63	49	29	82	64	63	50
Sterling	93	75	62	42	93	77	76	63
Titus	83	64	51	31	83	66	64	51
Hunter	103	85	72	51	103	87	86	73
Windham	118	102	88	68	118	104	100	90

Snowmaking Requirements – New York

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	cm	% change	% change	% change	cm	% change	% change	% change
Dry Hill	223	22	36	44	220	22	26	34
Gore	158	32	53	81	154	33	33	55
McCauley	151	33	55	85	148	33	33	57
Hickory	201	26	42	57	197	26	30	42
Oak	146	33	58	91	141	33	34	62
Royal	173	29	48	71	169	30	31	49
Snow Ridge	199	26	42	58	195	26	30	42
West	211	23	39	50	207	23	28	38
Whiteface	141	34	59	93	137	31	34	63
Willard	214	23	39	49	206	25	29	40
Brantling	236	1	14	-18	237	7	7	0
Bristol	219	8	14	1	220	14	14	10
Cockaigne	222	7	13	-1	221	14	15	10
Four Seasons	239	-1	0	-21	240	6	5	-3
Greek Peak	220	8	14	0	219	15	15	11
Holiday Vally	219	8	15	1	218	15	16	11
Peek'n Peak	224	6	11	-4	223	12	14	7
Song	223	6	12	-2	223	13	14	8
Swain	223	6	12	-2	223	13	14	8
Toggenburg	219	8	14	1	220	15	14	10
Holimont	229	4	8	-8	228	11	11	5
Kissing Bridge	226	5	10	-5	225	12	13	7
Labrador	225	5	11	-4	225	12	14	8
Woods	232	3	7	-10	232	10	10	4
Belleayre	192	14	24	17	195	14	14	14
Bobcat	156	17	25	39	157	16	14	24
Catamount	213	5	16	1	216	9	13	5
Cortina	163	18	25	35	166	16	14	22
Holiday Mountain	203	16	25	4	222	6	11	0
Mt. Peter	213	5	16	1	216	9	13	5
Plattekill	195	13	23	15	198	13	13	12
Sawsill	218	4	10	-8	221	6	11	0
Sterling	210	7	18	5	212	10	13	8
Titus	216	4	12	-7	220	8	11	1
Hunter	196	12	22	14	198	13	13	12
Windham	171	16	25	30	173	16	13	20

Probability of being operational during key holiday periods – New York

	AVG A1 1961-90	**AVG A1 2020s**	**AVG A1 2050s**	**AVG A2 2080s**	**AVG B1 1961-90**	**AVG B1 2020s**	**AVG B1 2050s**	**AVG B1 2080s**
	#	#	#	#	#	#	#	#
Dry Hill	90	66	39	23	88	74	61	49
Gore	94	88	69	51	95	90	85	77
McCauley	94	91	73	52	95	92	86	78
Hickory	91	73	55	36	91	82	73	62
Oak	95	92	75	53	95	93	86	78
Royal	94	84	66	44	94	87	83	75
Snow Ridge	91	73	55	38	91	82	74	63
West	90	69	50	30	90	81	67	54
Whiteface	95	93	80	57	95	93	86	80
Willard	93	69	50	30	90	79	66	54
Brantling	41	16	10	1	34	22	18	11
Bristol	65	37	14	8	58	34	32	19
Cockaigne	62	36	14	8	54	31	31	18
Four Seasons	35	14	10	1	29	19	14	7
Greek Peak	65	37	14	8	58	34	32	19
Holiday Vally	66	37	14	8	59	35	32	21
Peek'n Peak	59	33	11	7	52	30	26	16
Song	61	34	14	8	54	30	30	18
Swain	61	34	14	8	54	30	30	18
Toggenburg	65	37	14	8	58	34	30	17
Holimont	54	26	11	6	48	26	24	16
Kissing Bridge	59	33	11	7	50	28	25	16
Labrador	60	33	11	7	53	30	28	16
Woods	53	24	11	6	46	25	24	15
Belleayre	75	47	36	18	67	54	53	35
Bobcat	90	77	58	40	91	86	81	74
Catamount	60	32	19	8	54	37	32	19
Cortina	83	71	52	33	82	77	71	61
Holiday Mountain	52	28	12	4	44	28	30	14
Mt. Peter	60	32	19	8	54	37	39	19
Plattekill	75	46	33	18	67	54	51	32
Sawsill	52	27	12	4	43	25	30	14
Sterling	65	35	24	9	57	46	43	24
Titus	61	28	12	4	45	28	30	14
Hunter	72	44	30	17	65	51	51	32
Windham	80	67	46	32	78	71	69	53

1.6 Modeled results for ski areas in Vermont

Season Length with snowmaking (% change and # of days – Vermont

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	#	% change	% change	% change	#	% change	% change	% change
Jay Peak	172	-5	-13	-24	172	-5	-9	-11
Burke	164	-9	-16	-28	164	-7	-11	-14
Mad River	165	-8	-17	-29	165	-7	-12	-15
Middle bury	156	-9	-19	-32	156	-9	-12	-17
Sucicide Six	130	-11	-21	-38	130	-10	-13	-20
Killington	170	-7	-15	-26	170	-6	-9	-13
Pico	173	-5	-13	-24	173	-4	-8	-11
Sugarbush	171	-6	-14	-25	171	-6	-9	-12
Okemo	164	-8	-17	-30	164	-7	-11	-15
Ascutney	155	-11	-21	-34	155	-11	-14	-19
Smugglers N	157	-8	-18	-34	157	-8	-12	-17
Bolton	157	-8	-18	-33	157	-8	-12	-17
Stowe	165	-7	-16	-29	165	-7	-10	-15
Cochron	125	-14	-26	-46	125	-12	-14	-26
Bromley	171	-7	-15	-27	171	-6	-8	-12
Magic	163	-9	-17	-32	163	-8	-11	-16
Stratton	173	-5	-12	-24	173	-4	-6	-10
Mount Snow	171	-5	-12	-25	171	-5	-7	-11

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	days	days	days	days	days	days	days	days
Jay Peak	172	163	150	131	172	164	157	153
Burke	164	150	138	119	164	153	146	140
Mad River	165	151	137	117	165	153	146	140
Middle bury	156	141	127	106	156	143	138	130
Sucicide Six	130	116	103	81	130	117	113	104
Killington	170	159	145	125	170	160	155	149
Pico	173	164	151	132	173	166	160	154
Sugarbush	171	160	147	128	171	161	156	150
Okemo	164	150	136	115	164	152	145	139
Ascutney	155	138	122	102	155	138	134	126
Smugglers	157	144	128	104	157	144	139	130
Bolton	157	144	128	105	157	144	139	130
Stowe	165	153	138	117	165	154	148	141
Cochron	125	108	92	68	125	110	107	93
Bromley	171	160	146	126	171	160	157	150
Magic	163	149	135	110	163	150	145	137
Stratton	173	164	153	131	173	166	162	155
Mount Snow	171	162	150	128	171	163	160	152

Snowmaking Requirements – Vermont

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	cm	% change	% change	% change	cm	% change	% change	% change
Jay Peak	68	32	87	144	68	31	58	79
Burke	93	32	65	110	93	28	36	63
Mad River	88	33	68	114	88	27	41	65
Middle bury	105	32	60	98	105	27	33	57
Sucicide Six	149	27	50	73	149	25	30	46
Killington	71	44	94	143	71	38	58	79
Pico	59	49	111	173	59	41	68	94
Sugarbush	68	45	98	148	68	39	61	83
Okemo	90	38	75	114	90	34	45	68
Ascutney	114	36	63	93	114	32	35	58
Smugglers	98	34	64	106	98	31	36	58
Bolton	97	34	65	108	97	32	37	59
Stowe	79	36	77	130	79	32	47	70
Cochron	154	31	50	58	154	29	32	41
Bromley	61	61	114	182	61	49	68	103
Magic	85	51	87	132	85	48	51	83
Stratton	53	61	113	205	53	49	70	109
Mount Snow	58	52	106	186	58	48	66	98

Probability of being operational during key holiday periods – Vermont

	AVG A1 1961-90	AVG A1 2020s	AVG A1 2050s	AVG A2 2080s	AVG B1 1961-90	AVG B1 2020s	AVG B1 2050s	AVG B1 2080s
	#	#	#	#	#	#	#	#
Jay Peak	100	98	97	77	100	97	97	91
Burke	99	98	91	67	100	94	92	89
Mad River	98	96	87	65	98	96	93	90
Middle bury	96	94	80	59	96	93	92	87
Sucicide Six	93	74	55	26	93	78	72	56
Killington	99	93	89	74	99	96	94	92
Pico	99	95	90	78	99	97	94	94
Sugarbush	99	94	89	76	99	97	94	92
Okemo	97	93	83	65	97	96	90	89
Ascutney	94	85	74	55	97	88	90	82
Smugglers	94	91	75	53	94	91	87	80
Bolton	94	92	76	53	94	91	87	80
Stowe	98	93	85	70	98	92	89	85
Cochron	87	63	43	23	87	72	64	44
Bromley	99	94	83	72	99	95	92	92
Magic	98	92	79	65	98	93	86	87
Stratton	98	94	89	75	98	97	94	93
Mount Snow	98	94	86	73	98	97	93	92

2. Differential Vulnerability of Ski Areas in the US Northeast (economic sustainability)[4]

2010-39 A1fi (High Emissions)		
High Vulnerability	**Moderate Vulnerability**	**Low Vulnerability**
NY – (1) peek n' peak (2) cockainge, holiday valley, holimount, (3) kissing bridge (4) brantling (5) bristol (6) swain (8) woods (9) song (10) four seasons, labrador, toggenburg (11) greek peak (18) hunter, sawkill(19) belleayre, platekill, titus (20) mt peter, stirling; MA – (63) berkshire (64) blandford, otis (65) jiminy peak (66) butternut (67) nashoba (68) pine ridge, wachusett (69) blue hills (70) bousquet (71) bradford (72) ward; CT – (73) sundown (74) Mohawk (75) woodbury (76) Southington (77) powder ridge	NY – (7) dryhill (8) snowridge; VT – (25) cochran; NH – (40) black , whaleback (41) dartmouth (42) tenney (44) attiash (45) cranmore (46) king pine (48) ragged (49) gunstock (50) pats peak (51) crotched; ME – (53) black, mt abram (54) shawnee (57) new hermon (58) lost valley (61) camden	NY – (12) whiteface(13) gore (14) oak (15) mccauley(16) royal (17) west, Willard (18) cortina (21) bobcat; VT – (22) jay peak (23) smugglers notch (24) bolton , stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH –(37) balsams, loon (38) cannon (39) bretton (40) wildcat (43) watterville (47) sunapee ; ME – (52) saddleback, sugarloaf, sunday river (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson

2040-69 A1fi (High Emissions)		
High Vulnerability	**Moderate Vulnerability**	**Low Vulnerability**
NY – (1) peek n' peak (2) cockainge, holiday, holimount (3) kissing bridge (4) brantling (5) bristol (6) swain (7) dryhill (8) woods (9) song (10) four seasons, labrador, toggenburg (11) greek peak (17) willard (18) hunter, sawkill (19) belleayre, platekill, titus (20) mt peter, stirling; VT – (25) cochran; NH – (40) whaleback (41) dartmouth (42) tenney (44) attiash (48) ragged (49) gunstock (50) pats peak (51) crotched; ME – (53) black, mt abram, sunday river (54) Shawnee (57) new hermon (58) lost valley (61) camden; MA – (63) berkshire (64) blandford, otis (65) jiminy peak (66) butternut (67) nashoba (68) pine ridge, wachusett (69) blue hills (70) bousquet (71) bradford (72) ward; CT – (73) sundown (74) Mohawk (75) woodbury (76) Southington (77) powder ridge	NY – (8) snowridge, (16) royal (17) west (18) cortina (21) bobcat; NH – (40) black (45) cranmore (46) king pine (47) sunapee	NY – (12) whiteface (13) gore (14) oak (15) mccauley; VT – (22) jay peak (23) smugglers notch (24) bolton valley, stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat, ((43) watterville ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson

[4] High = Minimum of 100 day season length & 70-75% probability of being operational during key holidays
Moderate = Close to 100 day season length & at least 50% probability of being operational during key holidays
Low = Less than 100 day season length & less than 50% probability of being operational during key holidays

2070-99 A1fi (High Emissions)		
High Vulnerability	**Moderate Vulnerability**	**Low Vulnerability**
NY – (1) peek n’ peak (2) cockainge, holiday, holimount (3) kissing bridge (4) brantling (5) bristol (6) swain (7) dryhill (8) snowridge, woods (9) song (10) four seasons, labrador, toggenburg (11) greek peak (16) royal (17) west, willard (18) hunter, sawkill (19) belleayre, platekill, titus (20) mt peter, stirling (21) bobcat; VT – (25) cochran (36) suicide six; NH – (40) black, whaleback (41) dartmouth (42) tenney (44) attiash (45) cranmore (46) king pine (47) sunapee (48) ragged (49) gunstock (50) pats peak (51) crotched; ME – (53) black, mt abram, sunday river (54) Shawnee (57) new hermon (58) lost valley (61) camden; MA – (63) berkshire (64) blandford, otis (65) jiminy peak (66) butternut (67) nashoba (68) pine ridge, wachusett (69) blue hills (70) bousquet (71) bradford (72) ward; CT – (73) sundown (74) Mohawk (75) woodbury (76) Southington (77) powder ridge	NY – (13) gore (15) mccauley (18) cortina; ME – (62) mt jefferson	NY – (12) whiteface (14) oak; VT – (22) jay peak (23) smugglers notch (24) bolton valley, stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, Stratton (34) mt snow (35) burke; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat (43) watterville; ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw

2010-39 B1 (Low Emissions)		
High Vulnerability	**Moderate Vulnerability**	**Low Vulnerability**
NY – (1) peek n’ peak (2) cockainge, holiday valley, holimount, (3) kissing bridge (4) brantling (5) bristol (6) swain (8) woods (9) song (10) four seasons, labrador, toggenburg (11) greek peak (18) hunter, sawkill(19) belleayre, platekill, titus (20) mt peter, stirling; MA – (63) berkshire (64) blandford, otis (65) jiminy peak (66) butternut (67) nashoba (68) pine ridge, wachusett (69) blue hills (70) bousquet (71) bradford (72) ward; CT – (73) sundown (74) Mohawk (75) woodbury (76) Southington (77) powder ridge	NY – (8) snowridge; VT – (25) cochran; NH – (40) black , whaleback (41) dartmouth (42) tenney (44) attiash (45) cranmore (46) king pine (48) ragged (49) gunstock (50) pats peak (51) crotched; ME – (53) (53) black mt abram (54) shawnee (57) new hermon (58) lost valley (61) camden	NY – (7) dryhill (12) whiteface(13) gore (14) oak (15) mccauley(16) royal (17) west, willard (18) cortina (21) bobcat; VT – (22) jay peak (23) smugglers notch (24) bolton , stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH –(37) balsams, loon (38) cannon (39) bretton (40) wildcat (43) watterville (47) sunapee ; ME – (52) saddleback, sugarloaf, sunday river (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson

2040-69 B1 (Low Emissions)		
High Vulnerability	**Moderate Vulnerability**	**Low Vulnerability**
NY – (1) peek n' peak (2) cockainge, holiday, holimount (3) kissing bridge (4) brantling (5) bristol (6) swain (8) woods (9) song (10) four seasons, labrador, toggenburg (11) greek peak (18) hunter, sawkill (19) belleayre, platekill, titus (20) mt peter, stirling; NH –(50) pats peak; ME – (53) black, mt abram, sunday river (54) Shawnee (57) new hermon (58) lost valley (61) camden; MA – (63) berkshire (64) blandford, otis (65) jiminy peak (66) butternut (67) nashoba (68) pine ridge, wachusett (69) blue hills (70) bousquet (71) bradford (72) ward; CT – (73) sundown (74) Mohawk (75) woodbury (76) Southington (77) powder ridge	NY – (7) dryhill (8) snowridge, (16) royal (17) willard; NH – (40) black, whaleback (41) dartmouth (42) tenney (44) attiash (45) cranmore (46) king pine (51) crotched	NY – (12) whiteface (13) gore (14) oak (15) mccauley(17) west(21) bobcat (18) cortina; VT – (22) jay peak (23) smugglers notch (24) bolton valley, stowe (25) cochran (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, stratton (34) mt snow (35) burke (36) suicide six; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat, (43) (47) sunapee watterville (48) ragged (49) gunstock ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw (62) mt jefferson

2070-99 B1 (Low Emissions)		
High Vulnerability	**Moderate Vulnerability**	**Low Vulnerability**
NY – (1) peek n' peak (2) cockainge, holiday, holimount (3) kissing bridge (4) brantling (5) bristol (6) swain, woods (9) song (10) four seasons, labrador, toggenburg (11) greek peak, (18) hunter, sawkill (19) belleayre, platekill, titus (20) mt peter, stirling; NH – whaleback (41) dartmouth (42) tenney (44) attiash (48) ragged (49) gunstock (50) pats peak (51) crotched; ME – (53) black, mt abram, (54) Shawnee (57) new hermon (58) lost valley (61) camden; MA – (63) berkshire (64) blandford, otis (66) butternut (67) nashoba (68) pine ridge, wachusett (69) blue hills (70) bousquet (72) ward; CT – (73) sundown (74) Mohawk (75) woodbury (76) Southington (77) powder ridge	NY – (7) dryhill (8) snowridge (11) willard (17) west (18) cortina; VT – (25) cochran; NH – (40) black (45) cranmore(46) king pine(47) sunapee; ME – (53) sunday river (62) mt Jefferson MA – (65) jiminy peak (71) bradford	NY – (12) whiteface (13) gore (14) oak (15) mccauley(16) royal(21) bobcat; VT – (22) jay peak (23) smugglers notch (24) bolton valley, stowe (26) madriver (27) middlebury (27) killington, pico (29) sugarbush (30) okemo (31) ascutney (32) bromley (33) magic, Stratton (34) mt snow (35) burke(36) suicide six; NH – (38) cannon, (39) bretton (37) balsams (38) loon (40) wildcat (43) watterville; ME – (52) saddleback, sugarloaf (55) big rock (56) eaton (59) titcomb (60) big squaw

3. Skier Survey[5]

Skier/Snowboarder Survey

Dear Skier/Snowboarder,

This letter is an invitation to consider participating in a study I am conducting as part of my Doctoral degree in the Department of Geography at the University of Waterloo, Canada. Over the past few years the issue of climate variability and the impact that changing snow patterns may have on the ski/snowboard industry has been widely discussed. Studies suggest the ski/snowboard industry could be affected (positively or negatively) by the variability of natural snowfall and the ability to make snow. To gain a better understanding of how snow conditions may affect ski/snowboard tourism in the U.S. Northeast it is necessary to consider how people have responded to changing snow conditions in the past and how thy may react in the future.

Your participation in this study is entirely voluntary and would involve completing a short survey. The survey would take approximately 10-15 minutes of your time. In the survey you will be asked questions about your skiing/snowboarding experience and how you have or might in the future adjust your ski/snowboard patterns to changing snow conditions. You may decline to answer any of the questions. All the information you provide is completely confidential as your responses will be aggregated and summarized with those of hundreds of other skiers/snowboarders.

This study received ethics clearance from the Office of Research Ethics at the University of Waterloo (519-888-4567 ext. 36005, ssykes@uwaterloo.ca) and there are no known or anticipated risks to you as a participant in this study. If you have any questions or would like additional information about the study to assist you in reaching a decision about participation, you may contact my supervisor, Dr. Daniel Scott at (519) 888-4567 ext. 35497 or dj2scott@fes.uwaterloo.ca. If you wish to view the progression of this project you can visit my personal website at any time (www.fes.uwaterloo.ca/u/jpdawson) where you will find results when they become available.

By filling out this survey you are eligible to win one of six $100 gift certificates to the ski hill of your choice. Please fill out a ballot and return it to the researcher with the survey or place it in the box provided. Your opinions are very much appreciated and necessary to the success of this project! Thank you in advance for your assistance with this project.

Sincerely,

University of Waterloo

[5] Formatting of survey has been altered to fit this page

SECTION 1:
Ski / Snowboard Habits

1. Do you consider yourself a skier, a snowboarder or both? (*please check one box*)
   ☐ Skier ☐ Snowboarder ☐ Both

2. How many years have you been skiing/snowboarding? _______________

3. Please estimate how many times you have skied/snowboarded at <u>any resort</u> over the past 12 months

   ____

4. Please estimate how many times you have skied/snowboarded at <u>this resort</u> over the past 12 months

   ____

5. What is the length of <u>this</u> ski/snowboard trip? (*e.g. ½ day 1 day, 4 days*)

   ____

6. What is the average length of <u>a typical</u> ski/snowboard trip for you? (*e.g. ½ day, 1 day, 4 days*)

   ____

7. How often do you go skiing/snowboarding at resorts that are more than a three hour drive from your place of residence? (*e.g. once per year, once every three years, never . . .*)___________________

8. Do you hold a season pass to <u>this resort</u>? (*please check one box*) ☐ Yes, currently ☐ Yes, in the past ☐ No
   <u>If yes</u> how many years have you been a season pass holder? _____________

9. Do you hold a season pass at <u>another resort</u>?(*please check one box*) ☐Yes, currently ☐Yes, in the past ☐No
   <u>If yes</u> how many years have you been a season pass holder? _____________

10. When it snows at your place of residence do you think about going skiing more often than when it does not snow? (*please check one box*) ☐ Yes ☐ No

11. Does snowfall at your place of residence affect your decision to go skiing/snowboarding? (*check one box*)

    ☐ Yes ☐ No
    <u>If yes</u>, how?
    ____
    ____

12. How often do you check the snow conditions at your preferred ski resort? (*please check one box)*
    ☐ Whenever I go skiing/snowboarding ☐ Daily ☐ Weekly ☐ Monthly ☐ Never

13. What are the main factors that would influence you to continue to ski/snowboard at a particular resort? *(please circle 1, 2 or 3 for each statement)*

Reasons I would continue to ski/snowboard at a particular resort include:	Strong Influence	Minor Influence	No Influence
Close proximity to my place of residence	3	2	1
Price of lift tickets/passes	3	2	1
Quality of snow conditions	3	2	1
Presence of expert runs	3	2	1
Presence of beginner runs	3	2	1
Friends and family skiing there	3	2	1
Good service	3	2	1
Good facilities (e.g. accommodation, chalet, etc.)	3	2	1
Attractive nightlife	3	2	1
Presence of non-snow related activities available (e.g. pool, bar, restaurant, spa)	3	2	1
A lot of snowmaking capacity (e.g. comprehensive snowmaking system)	3	2	1
Absence of crowded slopes	3	2	1
Absence of crowded chalet/services	3	2	1
Other (please specify)	3	2	1

Note: *In questions 14 and 15 there are some questions that may seem similar. This is purposeful and designed solely for statistical purposes – thank you for your patience with this.*

14. Please answer the following questions about the importance of skiing/snowboarding to you (**i.e. the activity you selected in Q.1**) *(please circle your answer along this 5-point scale for each statement)*

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Skiing/snowboarding is one of the most enjoyable things I do	5	4	3	2	1
Skiing/snowboarding is very important to me	5	4	3	2	1
I find a lot of my life is organized around skiing/snowboarding	5	4	3	2	1
Skiing/snowboarding occupies a central role in my life	5	4	3	2	1
I enjoy discussing skiing/snowboarding with my friends	5	4	3	2	1
Most of my friends are skiers/snowboarders	5	4	3	2	1
When I participate in skiing/snowboarding, I can really be myself	5	4	3	2	1

I identify with the people and image associated with skiing/snowboarding	5	4	3	2	1
Participating in skiing/snowboarding says a lot about who I am	5	4	3	2	1
When I ski/snowboard, others see me the way I want them to see me	5	4	3	2	1

15. Please answer the following questions about <u>how you feel about your preferred ski resort (**i.e. the place**)</u>
(please circle your answer along this 5-point scale for each statement)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My preference to ski/snowboard at my preferred resort would not willingly change	5	4	3	2	1
To change my preferred resort would require major rethinking	5	4	3	2	1
I ski/snowboard at my preferred resort because their image comes closest to reflecting my lifestyle	5	4	3	2	1
When I ski/snowboard at my preferred resort it reflects the kind of person I am	5	4	3	2	1
My decision to ski/snowboard at my preferred resort was freely chosen from several alternatives	5	4	3	2	1
I did not control the decision on whether to ski/ snowboard at my preferred resort	5	4	3	2	1
I don't really know that much about my preferred resort	5	4	3	2	1
I am knowledgeable about my preferred resort	5	4	3	2	1

SECTION TWO:
Snow Conditions and Ski/Snowboard Participation Patterns

1. Have recent winters that had less than optimal snow conditions because of warmer than usual temperatures or lower than average snowfall, adversely affected your ski/snowboard participation? *(e.g. the winter of 2001-02 or the late start in 2006-07)(please circle 1 or 2 for each statement)*

Because of poor ski/snowboard conditions in the <u>past</u> have you:	Yes	No
Stopped skiing/snowboarding altogether for a full ski/snowboard season?	2	1
Travelled further to find better snow conditions within the U.S. Northeast	2	1
Taken a ski holiday outside of the U.S. Northeast region	2	1

Not purchased new ski/snowboard equipment/apparel	2	1
Done something else instead of skiing/snowboarding (e.g. another recreational activity)	2	1
Skied/snowboarded less often	2	1
Skied/snowboarded more often because of a shortened season	2	1
Stopped skiing/snowboarding for part of the winter	2	1
Waited for better snow conditions and resumed usual skiing/snowboarding frequency	2	1
Skied/snowboarded as often and in the same place(s) as usual	2	1

2. If the next 3 out of 5 ski/snowboard seasons had very little snowfall (*like in the winter of 2001-02*), how would this influence your decisions about if and where you would ski/snowboard:
(please circle 1, 2 or 3 for each statement)

If poor ski/snowboard conditions occurred in 3 out of the next 5 winters would you:	Yes	No
Stop skiing/snowboarding altogether for a full ski/snowboard season?	2	1
Travel further to find better snow conditions within the U.S. Northeast	2	1
Take a ski holiday outside of the U.S. Northeast region	2	1
Not purchase new ski/snowboard equipment/apparel	2	1
Do something else instead of skiing/snowboarding (e.g. another recreational activity)	2	1
Ski/snowboard less often	2	1
Ski/snowboard more often because of a shortened season	2	1
Stop skiing/snowboarding for part of the winter	2	1
Wait for better snow conditions and resume usual skiing/snowboarding frequency	2	1
Ski/snowboard as often and in the same place(s) as usual	2	1

3. If you have or think you might ski/snowboard less often under poor snow conditions what do you think you would do more of instead of skiing/snowboarding? (*please specify, e.g. spend more time with family, go on a golf or beach holiday, go shopping* . . .)
____
____
____
____
____
____

4. If your preferred resort were to experience very poor snow conditions would you be willing to pay more for a lift ticket than you currently do in order to offset the cost of improved snowmaking? (*check one box*)

   ☐ No ☐ Yes
   If yes, how much more would you be willing to pay (*i.e. 5%, 10%, 25% more than you currently pay*) ____________% more

5. If your preferred resort were to experience very poor snow conditions, would you be willing to pay more to travel to another resort where you would be guaranteed to be able to ski/snowboard? (*check one box*)

   ☐ No ☐ Yes
   If yes, how much more would you be willing to pay (*i.e. 5%, 10%, 25% more than you currently pay*) ____________% more

6. If you were to keep skiing in winters with very little natural snow, do you think you would plan short ski/snowboard trips close to your home *(e.g. day or weekend)* or would you plan extended ski/snowboard trips further from your home for a longer period of time *(e.g. one or two weeks)*?

   ☐ More short trips close to home ☐ More extended trips further from home ☐ Not sure

SECTION THREE:
About You

1. Do you own or rent your ski/snowboard equipment? (*please check one box*)
   ☐ Own ☐ Rent ☐ Own some/rent some

2. Do you own or rent a recreational property at or near your preferred ski area? (*please check one box*)
   ☐ Own property ☐ Own timeshare ☐ Rent property ☐ No

3. How many people are in your party today? __________

4. Who are you skiing/snowboarding with today? *(check all that apply)*
   ☐ Partner ☐ Children ☐ Parents ☐ Siblings ☐ Friends
   ☐ Acquaintances (people you met today) ☐ Other *(specify)*
   ____

5. Who do you usually ski/snowboard with? *(check all that apply)*
   ☐ Partner ☐ Children ☐ Parents ☐ Siblings ☐ Friends
   ☐ Acquaintances (people you met today) ☐ Other *(specify)*
   ____

6. Is this a typical skiing/snowboarding day for you? (*please check one box*) ☐ Yes ☐ No
   If no, explain why in one sentence

____
____
____

7. On which ski/snowboard runs do you feel completely comfortable? (*please check all that apply*)
   ☐ Beginner *(green circle)* ☐ Intermediate *(blue square*) ☐ Difficult *(single black diamond)*
   ☐ Expert (*double black diamond)*

8. Are you: (*please check one box*) ☐ Female ☐ Male

9. What is your place of residence: State/Province______________________
   City______________________

10. What year were you born? __________

11. What is the highest level of education you have attained? (*please check one box*)
    ☐ Elementary school ☐ High school ☐ College/University ☐ Graduate/Professional degree

~Thank you very much for your time~

Please provide any further comments in the box provided

4. List of Publications Related to this Study

Peer Reviewed Journal Articles

Dawson, J., Scott, D., & McBoyle, G. (2009). Climate change analogue analysis of ski tourism in the Northeastern US. *Climate Research*, 39(1), 1-9.

Dawson, J. and Scott, D. (2007). Climate change vulnerability in the Vermont ski tourism sector. *Annals of Leisure Research*, 10(3/4), 550-571.

Dawson, J., Maher, P., and Slocombe, D. S. (2007). Climate change, marine tourism and sustainability in the Canadian Arctic: contributions from systems and complexity approaches. *Tourism in Marine Environments*, 4(2/3), 69-83.

Scott, D., Dawson, J., and Jones, B. (2007). Climate change vulnerability of the US Northeast winter recreation-tourism sector. *Mitigation and Adaptation Strategies for Global Change,* 13, 577-596.

Peer Reviewed Conference Proceedings

Dawson, J., and Scott, D. (submitted). Examining climate change vulnerability of the of the US Northeast ski tourism sector using a systems-based approach. Proceedings of the 7th International Symposium on Tourism and Sustainability, Travel and Tourism in the Age of Climate Change: robust findings and key uncertainties, Brighton, England, July 9-10, Brighton: University of Brighton

Dawson, J., Scott, D., and McBoyle, G. (2007). Using an analogue approach to examine climate change vulnerability of the New England (USA) ski tourism industry. Proceedings of the 3rd International Workshop on Climate Change and Tourism (International Society of Biometerology), Alexandroupolis, Greece, 19 – 22 September. Freiburg: University of Freiburg, 183-190.

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Dawson, J. (2007). Climate change and behavioural adaptation in the tourism and recreation sector. Proceedings of the Graduate Student Leisure Research Symposium, University of Waterloo, 10 May. Waterloo: University of Waterloo.

Invited Book Chapters

Dawson, J., Stewart, E. J., Maher, P., and Slocombe, S. (2009). Climate change complexity and cruising in Canada's Arctic: a Nunavut case study. Invited chapter, In: Bone, R. *Natural Resources and Aboriginal People in Canada* (2nd edition)(eds), Captus Press: Concord, ON (page numbers not assigned yet).

5. List of Conference Presentations Related to this Study

Dawson, J. and Scott, D. (2009). Examining both supply-and demand-side vulnerability of the US Northeast ski sector to climate change. Paper presented at the Annual General Meeting of the Canadian Association of Geographers, Ottawa, Ontario, May 26-30.

Dawson, J. (2009). Climate change vulnerability for ski area managers. Invited presentation at the Ontario Snow Resorts Association 45th Annual General Meeting, Conference and Trade Show, Hockley Valley Resort, April 29-30.

Dawson, J. (2009). Modeling climate change vulnerability of the ski sector at a market-business scale. University of Waterloo IC3 Student colloquium, March 4-5.

Dawson, J., and Scott, D. (2008). The impact of climate change on the North American Ski Industry: an economic analysis. Invited presentation at 10 emes Entretiens de la montagne, L'economie touristique: piler du Development Durable. Chambery, France, November 6-7.

Dawson, J. (2008). Climate change vulnerability of important tourism activities in North America: an investigation of skiing and polar bear viewing. Invited presentation at The Tourism Educators Conference, Whistler, BC, May 8-10.

Dawson, J., and Scott, D (2008). The impact of climate change on the North American ski industry. Invited presentation at the 5th World Congress on Snow and Mountain Tourism, Encamp, Andorra, March 27-29.

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Glossary of Significant Terms

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Chapter 1

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