Mitig Adapt Strat Glob Change (2007) 12:1411–1431
DOI 10.1007/s11027-006-9071-4

ORIGINAL ARTICLE

Climate change adaptation in the ski industry

Daniel Scott · Geoff McBoyle

Received: 12 July 2006 / Accepted: 24 October 2006 / Published online: 2 December 2006

Abstract Regardless of the success of climate change mitigation efforts, the international community has concluded that societies around the world will need to adapt to some magnitude of climate change in the 21st century. While some economic sectors (e.g., agriculture, water resources and construction) have been actively engaged in climate change adaptation research for years, adaptation has received scant consideration within the tourism-recreation industry. This is particularly the case for adaptation by tourism operators (supply-side). One exception where progress on supply-side climate adaptation has been made is the ski industry. This paper provides a brief overview of the literature on the implications of climate change for the international ski industry and how adaptation by ski area operators has been treated within these studies. This is followed by an inventory of climate adaptation practices currently used by ski industry stakeholders, including the historical development of certain key adaptations and constraints to wider use. The characteristics of ski areas with higher adaptive capacity are identified. Considering the highly competitive nature of the ski industry and the generally low climate change risk appraisal within the industry, climate change adaptation is anticipated to remain individualistic and reactive for some time. With only a few exceptions, the existing climate change literature on winter tourism has not considered the wide range of adaptation options identified in this paper and has likely overestimated potential damages. An important task for future studies is to develop methodologies to incorporate adaptation so that a more accurate understanding of the vulnerability of the international ski industry can be ascertained.

Keywords Adaptation · Climate change · Ski industry · Tourism · Winter sports

D. Scott (✉) · G. McBoyle
Department of Geography, University of Waterloo, 200 University Avenue West, Waterloo, Ont., CanadaN2L 3G1
e-mail: dj2scott@fes.uwaterloo.ca

Introduction

In its Third Assessment Report, the United Nations Intergovernmental Panel on Climate Change (IPCC) (2001a) indicated that some degree of climate change was inevitable in the 21st century, regardless of the success of international efforts to reduce greenhouse gas (GHG) emissions. As a consequence, societies around the world will need to adapt to some magnitude of climate change in the decades ahead, adjusting human systems in order to moderate potential damages or realize new opportunities. The inevitability of the need to adapt to future climate change and the realization that adaptation is occurring today partially explain why ''(t)here has been an explosion of interest in adaptation to climate change over the past five years'' (Adger et al. 2005, p. 75). The agriculture, water resource and construction sectors in particular have been actively engaged in climate change adaptation research (Smit and Skinner 2002; de Loe et al. 2001; Lowe 2003). Stehr and von Storch (2005) argue further that climate research programmes and climate change policy urgently need to shift emphasis to adaptation.

Although the tourism and recreation sector is highly influenced by climate (Wall 1992; de Freitas 2003; Gomez-Martin 2005), our understanding of how climate variability affects the sector and its potential vulnerability to climate change remains limited (IPCC 2001b; World Tourism Organization 2003; Scott et al. 2005a; Hamilton et al. 2005a; Gossling and Hall 2006). Until recently, climate change had not garnered substantive attention from the tourism industry or the tourism and recreation research communities (Wall and Badke 1994; Scott et al. 2005a; Gossling and Hall 2006). Adaptation by tourists (demand-side) and tourism operators (supply-side) has had even less prominence in the developing literature on climate change and tourism-recreation, and remains an important research gap (Scott et al. 2003, 2005a; Hamilton et al. 2005a). A number of studies have begun to explore the potential adaptation of tourists to a changed climate (Maddison 2001; Lise and Tol 2002; Hamilton et al. 2005a, b; Jones and Scott 2006a, b; Scott and Jones 2006) and climate-induced environmental change (Braun et al. 1999, Richardson and Loomis 2004; Scott and Jones 2005; Uyarra et al. 2005; Scott et al. 2006). Research on supply-side climate adaptation in the tourism-recreation sector remains even more limited (Scott et al. 2002, 2003, 2005b; Raksakulthai 2003; Becken 2005; Wolfsegger et al. in press). One exception is the winter sports tourism segment, where studies from different nations have documented existing climate adaptation practices (Elsasser and Bürki 2002; Scott et al. 2003, Wolfsegger et al. in press) and in some cases analysed the effectiveness of specific adaptations (Scott et al. 2003, 2006; Hennessy et al. 2003; Scott and Jones 2005). There has not yet been a comprehensive review of climate adaptation in the ski industry, which is the purpose of this paper. Although the paper will largely focus on the North American ski industry, the discussion is generally applicable to the international ski industry and some examples of adaptation from other nations will be highlighted.

The paper is organized into three main sections. A brief introduction to the international ski industry is provided, followed by a summary of the literature on potential impacts of climate change and how adaptation by ski area operators has been treated within these studies. Next a portfolio of current climate adaptation practices used by ski area operators is identified and, where possible, the historical development of these adaptations and constraints to wider use within the industry discussed. By examining existing adaptation practices and identifying constraints to current adaptation, the paper will provide insight into the types of adaptation options that are likely to be used by ski area operators to cope with future climatic conditions and provide some criteria by which existing or future adaptive capacity of individual ski areas and skiing regions could be evaluated. The range of adaptation options identified also needs to be considered, as applicable to regional circumstances, in future climate change vulnerability assessments of the ski industry. The role of other key actors (skiers/riders, ski industry associations, financial sector, governments, communities) in determining the adaptive capacity of ski areas, currently and in the future, is also discussed.

The international ski industry and implications of climate change

The economic size of the global ski industry is difficult to determine because of differences in business models (single or multiple owners of ski lifts, restaurants and accommodations, ski schools, retail operations at a ski area) and the quality of data, however based on the available regional studies summarized below, direct revenues approach US$9 billion annually. In the US, members of the National Ski Areas Association (NSAA) had revenues of over US$3 billion in 2003 (NSAA 2004). In 2003, ski areas in Canada had annual revenues of approximately US$680 million (Statistics Canada 2005). Estimates by Lazard (2002), show the ski industry in Western Europe and Japan have annual revenues of over US$3 billion and US$1.4 billion respectively. In Australia, the ski industry was worth approximately US$94 million in 2000 (KPMG 2000). According to Lazard (2002), Western Europe represents the largest ski market with 54% of the estimated 330 million annual global skier visits, followed by North America (21%), Japan (16%) and Australia (1%).

Winter tourism and the ski industry more specifically, have been repeatedly identified as being particularly vulnerable to global climate change (Scott 2005). How much of this multi-billion dollar winter tourism industry is at risk? Climate change impact assessments of the ski industry have been conducted in a number of countries (Australia–Galloway 1988; Hennessy et al. 2003; Austria—Breiling and Charamza 1999; Canada—McBoyle and Wall 1987, 1992; Lamothe and Périard Consultants 1988; Scott et al. 2003, 2006; Scott and Jones 2005; Japan—Fukuskima et al. 2003; Switzerland—König and Abegg 1997; Elsasser and Messerli 2001; Elsasser and Bürki 2002; United States—Lipski and McBoyle 1991; Hayhoe et al. 2004; Casola et al. 2005). These studies have utilized different methodologies to examine the potential impacts of climate change on the ski industry and therefore are not directly comparable. Regardless of the methods employed, all studies in the literature have projected negative consequences for the industry in terms of reduced ski seasons, though to varying degrees and over different time frames (see Scott et al. 2006 for an overview of methods and projected impacts). No climate change assessments of the ski industry in Spain, Eastern Europe, South America, or China have been conducted, even though Lazard (2002) has identified these regions as having the greatest growth prospects in the next 20 years.

The aforementioned studies have been widely cited in IPCC (1996, 2001a) and other governmental assessments (ACACIA 2000; US National Assessment Team 2000; World Tourism Organization 2003; United Nations Environment Programme

2003). A major limitation of much of this literature is that it has not assessed the adaptive capacity of the ski industry. Only four of the 15 studies cited above (Scott et al. 2003, 2006; Scott and Jones 2005; Hennessy et al. 2003) have attempted to incorporate widespread adaptations by ski area operators, such as snowmaking, into climate change impact assessments. There could be sizable potential to reduce the projected negative impacts from climate change on the ski industry and consequently some of the existing literature may overestimate potential future damages.

Adaptation options

Researchers have developed several taxonomies of adaptation in the literature (Smit et al. 2000; Leary 1999; Klein 2003). In this paper adaptation options are organized by type of actor because, as in other economic sectors, adaptation in the tourism-recreation sector is comprised of the actions of many types of stakeholders (individuals, businesses, governments, communities and non-governmental organizations) that are motivated by different factors: quality of experience (skiers/riders), economic well-being (ski area operators, ski industry associations, communities, governments), and environmental and social sustainability (ski area operators, ski industry associations, communities, governments, and non-governmental organisations). The climate adaptations utilized by each of these major actors are presented in Fig. 1 and discussed separately below.

Ski area operators

The range of adaptation practices found among ski area operators can be organized into two main types: technological (snowmaking systems, slope development and operational practices, cloud seeding) and business practices (ski conglomerates, revenue diversification, marketing, indoor ski areas) (Fig. 1).

Snowmaking

Snowmaking is the most widespread climate adaptation used by the ski industry. The technology was first implemented in 1952 at the Grossinger Resort at Fahnestock, New York (US) and over the last 30 years has become an integral component of the ski industry in some regions (e.g., eastern North America, Australia, Japan). Hundreds of millions of dollars have been invested in snowmaking systems as ski areas attempted to expand their operating season and increase the range of climate variability with which they could cope.

The United States has particularly good information on the historical diffusion of this climate adaptation. Figure 2 shows the implementation of snowmaking technology from 1974–1975 to 2001–2002 in the five ski regions of the US. In the mid-1970s there was a greater use in the Northeastern and Midwest regions than the regions with higher elevations like the Rocky Mountains and the Pacific West. Since then that difference has been diminishing. Today, all ski areas in the Northeast, Southeast and Midwest ski regions use snowmaking to some extent, with the amount of skiable terrain covered by snowmaking in 2001–2002 varying from 62% in the Northeast, to 95% in the Southeast, and 98% in the Midwest. While the majority of

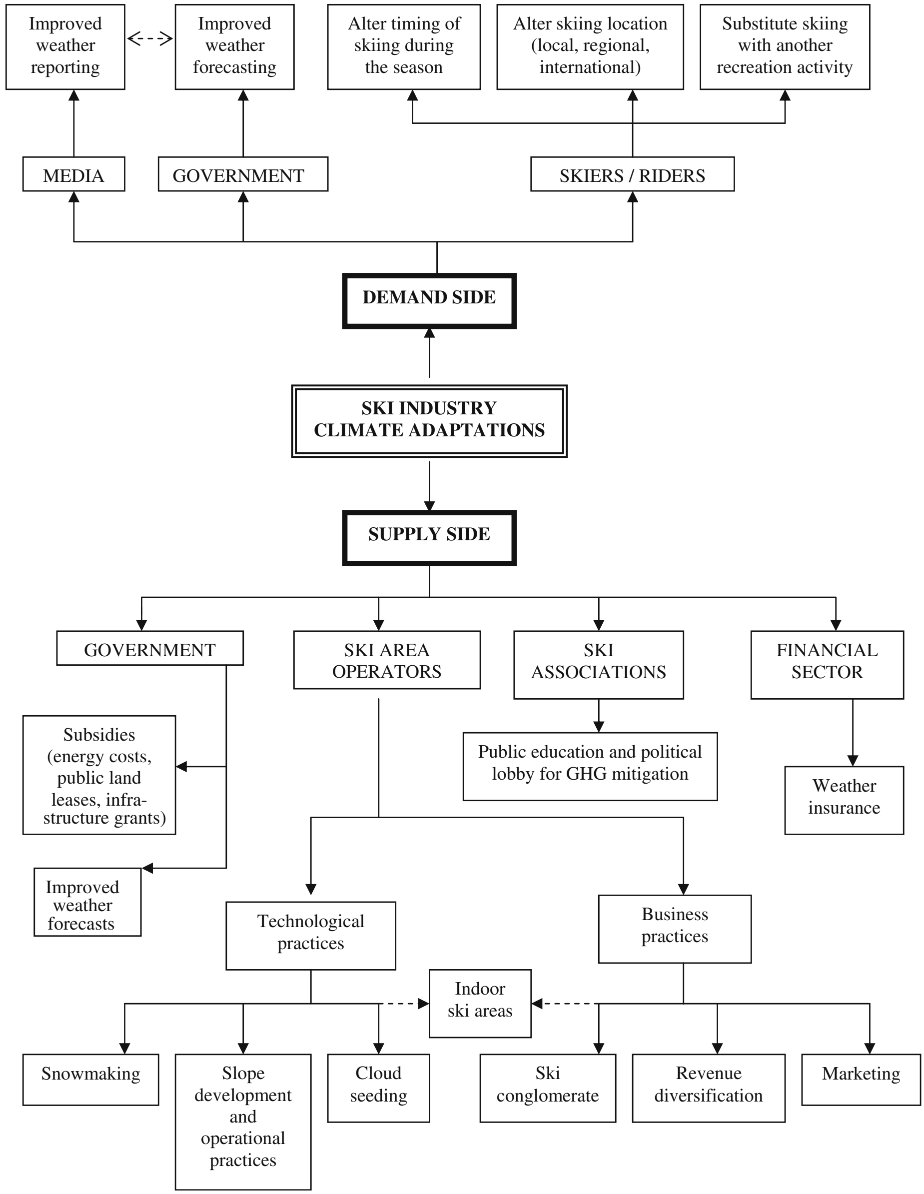

Fig. 1 Climate adaptation options in the ski industry

ski areas in the Rocky Mountains (89%) and the Pacific West (66%) regions now employ snowmaking, the proportion of skiable terrain covered remains much lower (13% and 8% respectively). A similar east-west geographic pattern and historic pattern exists in Canada as well (Scott et al. 2006). The implementation of snow-making is not as extensive in Europe as in North America, but there is no comprehensive analysis of how snowmaking differs by country or its historic diffusion in that region.

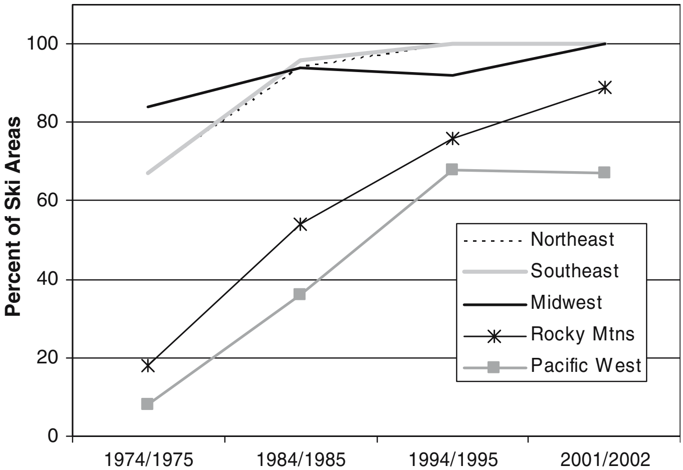

Fig. 2 US ski areas with snowmaking systems. *Data source*: National Ski Areas Association annual state of the ski industry reports

The importance of snowmaking as an adaptation to climate variability cannot be overstated. In their analysis of six ski areas in eastern North America, Scott et al. (2006) found that snowmaking extended the average ski season between 55 days and 120 days during the baseline period (1961–1990) (Table 1). Although snowmaking currently provides large economic dividends in this region, Table 1 illustrates that its importance will increase under projected climate change, as the difference in the length of ski seasons with natural snow cover and with snowmaking-enhanced snow cover increases at each location. A comparison of results for similar climate change scenarios between Scott et al. (2006) and earlier studies that did not incorporate snowmaking, also demonstrated how important this adaptation was in reducing the vulnerability of the ski industry in eastern North America to climate change.

Large increases in snowmaking requirements under climate change scenarios also raises important questions about the sustainability of this adaptation strategy in certain locations. Communities and environmental organizations have expressed concern about the environmental impact of water withdrawals associated with snowmaking. When water for snowmaking is withdrawn from natural water bodies (streams and lakes), water levels may be reduced at critical times of the year, impacting fish and other marine species. Some jurisdictions have strict regulations governing water withdrawals for snowmaking. For example, the State of Vermont implemented a ‘February Mean Flow’ (FMF) standard, where water withdrawals for snowmaking are not permitted when natural watercourses are at or below the average mean flow. Any expansion of snowmaking activities must remain within the standard. Under the warmest 2050s scenario for Vermont, where a doubling of snowmaking was modelled at one ski area (Scott et al. 2006), maintaining the FMF standard may be severely tested. Construction of water reservoirs may address this constraint. For example, the Okemo ski area in Vermont has already built the largest snowmaking reservoir in the region (264 million-litre capacity), enabling the resort to ‘stockpile’ water during the spring and summer for winter use. In other ski regions where water supplies are more limited or greater competition for water exists, access to water is likely to be a critical constraint for snowmaking. For example, owners of

Table 1 Modelled natural and snowmaking adapted ski seasons in eastern North America

Study area	Baseline (1961–1990) days			Climate change (2020s) days			
	Natural snow	With snowmaking	Difference	Scenario	Natural snow	With snowmaking	Difference
Brighton, Michigan	6	115	+99	Least-change	1	109	+108
				Warmest	0	83	+83
Orillia, Ontario	60	150	+90	Least-change	24	146	+122
				Warmest	9	122	+113
Quebec City, Quebec	99	160	+61	Least-change	87	158	+71
				Warmest	59	139	+80
Rutland, Vermont	13	119	+106	Least-change	4	113	+109
				Warmest	1	89	+88
Ste. Agathe-Des-Monts, Quebec	108	163	+55	Least-change	89	163	+74
				Warmest	53	142	+89
Thunder Bay, Ontario	44	164	+120	Least-change	33	161	+128
				Warmest	7	136	+129

Data source: based on modelling outputs of Scott et al. (2006)

the three ski areas inside Banff National Park in Alberta, Canada, say their access to water for snowmaking and other infrastructure improvements needed to remain internationally competitive is severely constrained by the requirement to show the development restores or improved ecological integrity (Maloney 2005).

Other potential constraints to this vital climate adaptation also exist. Even where snowmaking is climatically feasible and water supplies can be secured, the additional infrastructure costs and the energy costs associated with large increases in snowmaking volumes and making snow at higher average temperatures may be uneconomic to some ski operators. In areas where snowmaking may become climatically marginal, public resistance to the use of chemical additives to allow ice particle formation at temperatures near 0°C may limit snowmaking at times when it is needed most.

Slope development and operational practices

At existing ski areas, slope development adaptations include: slope contouring, landscaping, and the protection of glaciers. Contouring or smoothing ski slopes (i.e., grooming slopes in the summer season to remove rocks or shrub vegetation) reduce the snow depth required to operate and represent a cost saving strategy for snowmaking. Land contouring can also be used to capture snowmelt and replenish snowmaking reservoirs throughout the winter. Strategic planting or retention of tree cover can capture moving snow ('snow farming') and partially shade ski slopes, reducing snowmelt and snowmaking requirements. Retreat of glaciers has been observed to be a global trend in the later part of the 20th century (IPCC 2001b) and ski areas have utilized two distinct strategies to preserve glaciers deemed important to their operations. With the increased recession of glaciers in the Alps in recent years, notably the record warm summer of 2003, ski areas in Switzerland and Austria, have begun to install large sheets of white polyethylene on critical areas of glaciers to protect the ice from ultraviolet radiation and restrict melting during summer months (Simmons 2005; Jahn 2005). On the other hand, Whistler–Blackcomb ski resort in Canada is considering an engineering plan to protect and even grow the glacier at the top of Blackcomb Mountain by installing snow fences and using snowmaking near the summit to provide additional snow inputs for the glacier (Efron 2005).

In addition to the modification of existing skiable terrrain, the development of new skiable terrain in climatically advantaged locations is commonly cited as an adaptation to climate change. The development of north facing slopes, which retain snowpack longer, is one strategy. An example of this strategy is the Intrawest Company's planned expansion of the Mont Tremblant ski area in Quebec, Canada, to develop two new pedestrian ski villages on the north side of the mountain (Versant Nord). Expansion of ski areas into higher elevations, where snow cover is generally more reliable and a longer ski season is possible, appears to be one of the principal climate change adaptation strategies being considered by ski area operators in the European Alps (König and Abegg 1997; Elsasser and Bürki 2002; Breiling and Charamza 1999). Elsasser and Bürki (2002) noted that, while Swiss ski area operators have tended to discount the threat posed by climate change, they nonetheless use the potential of climate change to justify expanded development into higher elevations. Thirty-six ski areas in Austria applied for permits to expand their operations into higher elevations in 2002–2003 (Tommasini 2003). Wolfsegger et al. (in press) found expanding to higher elevations was the third most preferred climate change adaptation strategy by Austrian ski area managers, after snowmaking and sharing snowmaking costs with the accommodation industry. High elevation mountain environments are particularly sensitive to disturbance and opposition from the public and environmental groups may pose a significant constraint on this adaptation strategy in some locations. For example, a project to develop a world-class, four-season ski resort on Jumbo Glacier in southern British Columbia has been held up since 1991 by opposition from environmental groups and local residents (Greenwood 2004). In 1998, the radical environmental group Earth Liberation Front caused over US$12 million in fire damage to infrastructure at Vail Resort (Colorado) when forest clearing began for a 1000-acre expansion of the ski area (Faust 1998).

Adaptations in the timing of ski area openings may be required in some locations if climate change makes early season snowmaking uneconomic. Throughout much of North America and Europe the ski season prior to the Christmas-New Year holiday period represents a low proportion of annual skier visits. Under climate change, the increased costs of attempting to open long before this economically important holiday period may mean this early-season is no longer viable. Increasing the intensity of use at a ski area by raising lift capacity or limiting slope availability to concentrate snowmaking resources, is a strategy to reduce operating costs, but increased utilization levels will prove effective only if skier satisfaction can be maintained.

Artificial, non-snow ski surfaces were first developed in the 1970s. These surfaces have improved to an extent that they are now provide reasonable gliding and edging properties that do not damage ski equipment. Although the technology is little used currently, there may be niche applications on ski slopes in the future, for example as a surface in high traffic ski areas (e.g. under tow bars) or on small training slopes, snowboarding parks and snowtube-toboggan runs.

Cloud seeding

Cloud seeding is a weather modification technology that has been used to produce additional precipitation, mainly for agricultural purposes. Some ski areas in North America and Australia have also employed this technology in an attempt to generate additional snowfall. Four ski resorts in Colorado (US) (Telluride, Durango, Vail, and Beaver Creek) have used cloud seeding in the past. Vail Resorts have had a cloud seeding program for 23 years and reportedly spend US$134,000 annually on this climate adaptation (Horrocks 2001); this despite a recent US government report (National Research Council 2003) which concludes there still is no convincing scientific evidence that cloud seeding works. In 2004, the New South Wales State Government in Australia approved a US$15 million, five year cloud seeding project for the Snowy Mountains, intending to increase snowfall by 10%. Records show that snowfall has declined by approximately 1% per year over the last 50 years and climate change was projected to have a devastating impact on the region's ski industry in the future (Hennessy et al. 2003). The cloud seeding initiative in New South Wales is also intended to increase water resources for hydroelectric generation and crop irrigation in summer months. Conversely, Wolfsegger et al. (in press) found cloud seeding to be the least preferred climate change adaptation strategy by Austrian ski area managers.

Ski conglomerates

An important business model to emerge in the ski industry over the past decade is the ski resort conglomerate. Companies like American Skiing Company, Intrawest, Booth Creek Resorts, and Boyne USA Resorts have acquired ski areas in different locations across North America (Table 2). Although not intended as a climate adaptation, the conglomerate business model may prove to be one of the most effective adaptations to future climate change. The ski conglomerate business model provides greater access to capital and marketing resources, thus enhancing adaptive capacity, but also reduces the vulnerability of the conglomerate to the effects of climate variability and future climatic change, through regional diversification in business operations. The probability of poor snow conditions in a single ski region of North America (e.g., just New England) is much higher than for several regions simultaneously (e.g., all of New England, Quebec-Ontario, Midwest, Rocky Mountains, and California). When poor conditions occur, the financial impact can be spread out through the organization and above average economic performance in one or more regions could buffer losses in another. Companies with ski resorts in a single region or independent small–medium size ski enterprises are at greater risk to poor climatic conditions. Without substantive economic reserves or access to capital, a series of economically marginal years may be all that is required to bankrupt the business.

The greater adaptive capacity of the ski conglomerate business model was illustrated during the 2004–2005 ski season in the Pacific Northwest region of the US. Skier visits in the state of Washington declined 78% from 2001 to 2002 because of warm temperatures and frequent rain. The Summit at Snoqualmie Resort, which is part of the Booth Creek conglomerate, sent many laid-off seasonal employees to other Booth Creek resorts in California, 2004–2005 season passes were honoured at any Booth Creek ski area, and the parent company allowed the resort to honour 2004–2005 season passes for the 2005–2006 season in order to maintain its core

Table 2 Regionally diversified ski conglomerates in North American[a]

American Skiing Company		Intrawest	
Mount Snow	Vermont	Whistler Blackcomb	British Columbia
Killington/Pico	Vermont	Panorama	British Columbia
Sunday River	Maine	Tremblant	Quebec
Sugarloaf	Maine	Blue Mountain	Ontario
Attitash Bear Peak	New Hampshire	Mammoth Mountain	California
The Canyons	Utah	Snowshoe/Silver Creek	West Virginia
Steamboat	Colorado	Stratton	Vermont
		Copper Mountain	Colorado
		Vernon Mountain Creek	New Jersey
Boyne USA Resorts		Booth Creek Resorts	
Big Sky Resort	Montana	Loon Mountain	New Hampshire
Boyne Highlands	Michigan	Cranmore Mountain	New Hampshire
Boyne Mountain	Michigan	Waterville Valley	New Hampshire
Brighton	Utah	Northstar-at-Tahoe	California
Crystal Mountain	Washington	Sierra-at-Tahoe	California
Cypress Mountain	British Columbia	The Summit	Washington

[a] Other ski conglomerates exist (e.g., Rocky Mountain Resorts, Vail Resorts) but are not regionally diversified

customer base (Goodman 2005). In contrast, an independent ski area in the same region was forced to forego investment plans, including repairs to a chair lift, and indicated it would be in 'recovery mode for several years' (Goodman 2005).

Revenue diversification

Over the past three decades, many ski areas in North America have diversified their operations beyond traditional ski activities to include the provision of skiing and snowboarding lessons, accommodation and retail sales. The Economist (1998) referred to the transition of major ski resorts in North America from ski areas to winter theme parks, as the 'Disneyfication' of the winter sports industry. Non-skiers represent an important market at ski resorts. Williams and Dossa (1990) estimated that 20–30% of visitors to ski resorts in Canada did not ski during their visit. A similar pattern was found for visitors to winter resorts in France (Cockerell 1994) and Switzerland (Wickers 1994). Many ski resorts have made substantial investments to provide alternate activities for non-skiing visitors (e.g., snowmobiling, skating, dog sled-rides, indoor pools, health and wellness spas, fitness centres, squash and tennis, games rooms, restaurants, retail stores). Table 3 illustrates how revenue sources at ski areas in the US have evolved. In 1974–1975, lift tickets represented almost 80% of revenues for the typical ski area in the US. Today lift tickets represent less than half the revenue base, as other activities have risen in importance. A number of former 'ski resorts' have further diversified their business operations to become 'four season resorts', offering non-winter activities such as golf, boating and white-water rafting, mountain biking, paragliding, horseback riding and other business lines. At many larger resorts, real estate construction and management has also become a very important source of revenue.

Marketing incentives

Ski companies have already begun to experiment with incentives or guarantees to overcome skiers' reluctance to book a ski holiday because of uncertain snow conditions. In the winter of 1999–2000, for example, the American Skiing Company promised visitors to its six New England region ski resorts a 25% reduction on their next vacation if the ski area failed to open 70% of their ski runs during the Christmas-New Year holiday period. Warm temperatures that season forced three of the six resorts to pay customers rebates (Keates 2000). If supportable through

Table 3 Ski area revenue sources

Revenue sources (%)	1974–1975	2001–2002
Lift tickets	79.4	47.4
Food and beverages	2.8	14.1
Lessons	2.8	9.8
Accommodation/lodging	1.8	9.4
Other	2.1	7.2
Retail	1.5	5.5
Rentals	4.5	5.3
Property operations	5.1	1.2

Data source: NSAA annual state of the ski industry reports weather derivative products (see discussion in 'Financial Sector' to follow), this marketing strategy may become more prevalent in the ski industry, but will be countered by the general trend in the tourism industry toward shorter travel planning timeframes (i.e., 'last minute' bookings).

Indoor ski slopes

The first known indoor skiing slope, the 'Casablanca Dome', opened in Belgium in 1986 and since then, many technological advances have been incorporated into the more than 50 indoor ski domes operating globally in 2005 (Thorne 2006). The majority of ski domes are in Europe and Japan, with the largest facility now operating in Dubai. No ski domes are in operation in North America, but one is in the planning phase for New Jersey. The major value of indoor ski domes as a potential climate change adaptation is in encouraging early ski interest in urban areas as the forerunner of future skier demand at traditional resorts. For example, with low elevation ski areas near major urban markets in the eastern US (e.g., Boston, New York) expected to be highly vulnerable to climate change, the development of indoor ski domes in these major markets could be an important strategy by the US ski industry to maintain continued market development.

Skiers/riders/tourists

Most of the climate change assessments of the skiing industry have focused on potential impacts to ski operators (i.e. tourism/recreation supply). The potential impact of climate change on skiing demand and the adaptability of skiers/riders is a very important dimension that has been largely neglected.

Skiers/riders are very adaptable to climate variability, as they can easily alter the destination and timing of their skiing trip, or substitute skiing with another recreation activity (e.g., a beach holiday, going to an indoor water park). Behringer et al. (2000) and König (1998) utilized surveys to examine how skiers/rider might respond to marginal ski conditions in the future. Bürki (2000) asked skiers at five Swiss ski areas how they would change their skiing patterns if conditions in a hypothetical climate change scenario were realized. Specifically, skiers were asked, "Where and how often would you ski, if you knew the next five winters (at the survey location) would have very little natural snow?" The majority (58%) indicated they would ski with the same frequency (30% at the same resort and 28% at a more snow reliable resort). Almost one-third (32%) of respondents indicated they would ski less often and 4% stated they would stop skiing altogether. With more than one-third of the sampled ski market skiing less or quitting, the implications of climate change for skiing demand in Switzerland are potentially significant.

König (1998) conducted a similar survey at three Australian ski areas. With the same scenario of very little natural snow for five years, only 25% of respondents indicated they would continue to ski with the same frequency in Australia. Nearly one-third (31%) would ski less often, but still in Australia. An even greater portion of the ski market would be lost to the Australian ski industry, with 38% of respondents indicating they would substitute destinations and ski overseas (mainly to New Zealand and Canada) and a further 6% no longer skiing at all. With 44% of the ski market potentially lost and 31% skiing less often, the implications of climate change for Australia's ski industry would appear ominous.

No attempt was made in either study to assess the implications of projected changes in demand from the ski industry's perspective (i.e., would the ski industry still be economically viable) or how ski area operators might adapt to reduce losses in skiing demand. These remain important questions for future inquiry.

Using annual skier visitation data, Scott (2005) found evidence of skier/rider behavioural adaptation to current climate variability that provides additional insight into the potential implications of climate change. The winters of 2000–2001 and 2001–2002 in eastern North American provide an important contrast, with the former representing temperatures close to the 1961–1990 normal in southern Ontario, southern Quebec and many of the New England states, and the later representing the record warm winter and a potential analogue for a mid-range 2050s scenario (i.e., approximately 4.5°C warmer than 1961–1990). Consistently lower skier/rider visitation was found in the climate change analogue winter (2001–2002): –11% in the Northeast ski region of the US, –7% in Ontario, and –10% in Quebec (NSAA 2004; Canadian Ski Council 2004). Although this finding is not surprising, what was unexpected was how small the reduction in visitation was during the climate change analogue ski season compared to the aforementioned findings of Bürki (2000) and König (1998). Pricing changes and other incentives (see discussion) were used by individual ski operators in these regions as an adaptation to attract skiers when marginal conditions existed and to increase visitation when conditions improved.

Another possible explanation for the lower than expected decline in skier/rider visits is the temporal substitution of visits by skiers. In a shorter ski season skiers/riders can participate more frequently and still ski as much as they would in a normal year (i.e., go skiing every weekend, instead of every three weeks). This type of behavioural response is even more probable during ski seasons that start later than usual, because skiers know they are likely to have fewer opportunities to ski that season. This type of behavioural adaptation by skiers can be seen in a measure of ski area 'utilization' recorded by the NSAA in the US. Utilization is an economic measure of the ratio of actual skier visits to the physical capacity of skier visits at a ski area over the ski season (calculated as the daily visitor capacity multiplied by the number of days of operation). The trend line in Fig. 3 indicates that utilization

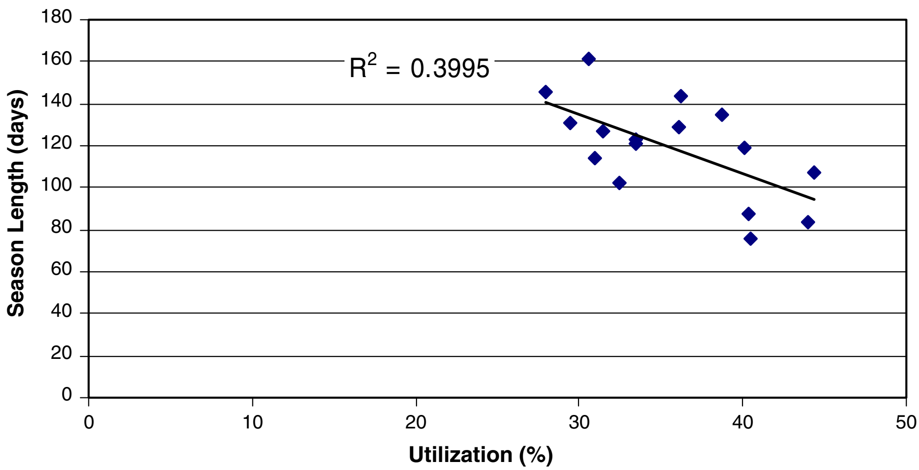

Fig. 3 Ski area utilization in the Northeast ski region (1974–1975 to 1995–1996). *Data source*: National Ski Areas Association state of the ski industry reports (1975–1996)

decreases during longer ski seasons. Greater utilization during shorter ski seasons, suggests that behavioural adaptation by skiers is indeed occurring in this region. Further research is needed to confirm whether this type of adaptation takes place in other ski regions around the world, to what extent, and how such behavioural adaptation differs during a single poor season and multiple consecutive poor seasons (the latter being expected under climate change). Survey research about skier adaptations during climate change analogue seasons is also needed in these same ski regions to better understand adaptation decision making and how adaptations differ among segments of the ski market (e.g., core versus occasional skiers).

Ski industry associations

The skiing industry in Europe and North America is beginning to become more actively engaged in discussions of climate change vulnerability, as evidenced by several workshops and invited presentations over the past five years. Best (2003) has pointed out that the ski industry in the US has undergone a remarkable turnaround in its position on global climate change over the last few years. Where once it discounted the risks of climate change, the industry has now become actively involved in the promotion of GHG mitigation strategies.

In partnership with the Natural Resources Defence Council (an environmental organization) the NSAA in the US initiated the 'Keep Winter Cool' campaign in 2003. The objective of the campaign is to combat climate change through public education at ski areas (including incentives for energy efficient travel options), through GHG reductions within the ski industry (a wide range of energy efficiency and renewable energy initiatives), and through a coordinated political lobby by the winter tourism industry to support government GHG reduction policies in the US (65 ski areas lobbied state and national governments to support the proposed Climate Stewardship Act in the US).

In contrast to its coordinated actions on climate change mitigation, a climate change adaptation strategy has not been developed by the US ski industry. The North America ski industry is a very competitive business environment, where the tradition of cooperation is largely limited to government lobbying, regional marketing of winter tourism, and environmental standards. Consequently, it is difficult to conceive of the industry developing a cooperative adaptation plan, that might include, for example, a national income stabilization program to spread the climate risk exposure of individual ski areas or support vulnerable ski areas near major urban markets like Boston and New York, which play an important market development role for the industry as a whole. The more likely scenario is a continuation of the existing competitive business environment and the unplanned contraction of the US ski industry that has been underway for the past two decades. The total number of ski areas in the US has declined from 735 in 1983 to 492 in 2005 (NSAA 2006).

Financial sector

There is growing general awareness of climate change risk in the business community (Reuters 2004; The Wall Street Journal 2005). For example, Hypovereinsbank and Credit Suisse consider climate change in credit risk and project finance assessments (Innovest Strategic Value Advisors 2003). The investment community has also begun to adapt its lending practices to the ski industry. Swiss banks now provide very restrictive loans to ski areas at altitudes below 1500 masl (Elsasser and Bürki 2002) and banks in Canada are known to have discussed the implications of climate change during financial negotiations with ski operators (Scott 2005).

Snow insurance and weather derivative products have been made available to the ski industry by companies such as Société Générale SA and Goldman Sachs, and through the Chicago Weather Derivatives Exchange. During the 1999–2000 ski season Vail Resorts in Colorado purchased snow insurance that paid the resort US$13.9 million when low snowfall affected skier visits (Bloomberg News 2004). However, insurance premiums have increased substantially in the last 5 years, possibly reflecting adaptation of this insurance product by the financial sector, and large ski corporations like Intrawest and Vail Resorts no longer carry weather insurance because of the high premiums. Snow insurance costs are likely to be more burdensome on smaller business and therefore unlikely to be used to a great extent in the ski industry in their current form.

Government (local, state, national)

Improved climate forecasting

Improved weather forecasting would provide a better basis for risk assessments and strategic business decisions, including the timing of seasonal openings (when to commence snowmaking) and the purchase of weather insurance. Discussions with ski area operators in eastern North America suggest that the industry does not currently use seasonal forecasts in their operational decision-making and substantive improvements in forecasting accuracy would be required before these products would reach a level of practical utility for the ski industry. Some ski area operators even view five to seven day forecasts as too unreliable for operational decision-making and used forecasts from other countries or private services in place of government issued forecasts.

Another dimension of forecasting that could be improved in some regions is its communication to the public through the media. Ski operators sometimes have adversarial relationships with some local media because of what they perceive as inaccurate reporting of weather conditions and forecasts that they argue cost them business (see King 2005 for some examples). Some ski operators also have reputations for overly positive interpretations of snow conditions and weather forecasts. In response, many ski areas have installed real-time web cameras to show potential customers actual snow and weather conditions. Accurate reporting of snow conditions and weather forecasts is important for overcoming the 'urban backyard phenomenum' observed in several ski regions, where skier demand is influenced by snow conditions in the backyards of urban markets, which may not in way resemble snow conditions at ski areas that are sometimes hundreds of kilometres away. Collaboration between ski industry stakeholders and the media to improve the accuracy of snow and weather reports is a demand-side adaptation that is likely to become even more important to skiers and ski operators in an era of climate change, as conditions become more marginal in some ski areas and the difference between snow conditions in urban markets and ski areas potentially increases.

Government policy

Government assistance to the ski industry has occurred in the form of discounted energy prices, long-term leases of public lands and infrastructure grants, but the industry has not benefited from the types of assistance programs available to other weather-sensitive economic sectors (e.g., subsidized crop insurance for the agriculture sector). In the future, skiing-related tourism economic losses resulting from adverse weather conditions may be sufficient for government concern and support in some regions. Government involvement in the ski industry's future could take several forms. Direct intervention could come through subsidies, insurance support or marketing initiatives. Indirectly, government policies relating to land and water use, and energy consumption and pricing could impact skiing operations positively (or negatively). Government subsidies for snowmaking were highly supported by Austrian ski area managers, while government support for economic losses following poor winters was only moderately supported (Wolfsegger et al. in press).

Discussion

The paper has identified a wide range of climate adaptation options utilized by ski industry stakeholders and provided examples of constraints that are likely to limit the implementation of various adaptation options in some locations. This review provided a number of insights into potential climate change adaptation by the ski industry. Climate adaptations by ski area operators are not isolated from other business decisions and are influenced by a wide range of other factors (e.g., market demand, competition, energy costs, labour availability and costs, environmental regulations). As has been noted by Smit et al. (2000) and Adger et al. (2005) with regard to adaptation in other economic sectors, it was difficult to sort out adaptations in the ski industry that were driven mainly by climate and those that are the result of other non-climate factors. Discussions with ski industry stakeholders suggest that most climate change adaptations are likely to be incremental adjustments of existing strategies to reduce risks posed by current climate variability. Many North American ski area managers have indicated they perceive the risk of climate change to be very low over any relevant business-planning horizon. Wolfsegger et al. (in press) found similar perceptions among ski area managers in Austria, which was due largely to the belief that further climate adaptation would allow their business to remain economically viable. Climate change adaptation in the ski industry is therefore likely to remain reactive. Indeed, we found little evidence that ski areas were engaged in long-term business planning in anticipation of future changes in climate. This does not discount the possibility that proactive climate change adaptation strategies are not being developed by some forward-looking ski operators, like Aspen Ski Company, which has had a climate change policy since 2001 and joined the Chicago Climate Exchange (North America's first voluntary, legally binding multi-sector market for reducing and trading GHG emissions) in 2005, and whose Chief Executive Officer, Patrick O'Donnell, recently referred to climate change as 'the most pressing issue facing the ski industry today' (Erickson 2005). Nonetheless, the only climate change specific adaptations found were focused on public education and political lobbying to strengthen mitigation efforts. We are unaware of any ski area that has completed a climate change risk analysis.

Climate change adaptation in the ski industry is also anticipated to remain largely individualistic for a number of reasons. The availability of adaptation options will be very context-specific and vary according to geographic characteristics (e.g., microclimate, available high elevation terrain for expansion, and distance to large urban markets), government jurisdiction (e.g., water access rights in different states/provinces or inside/outside of national parks) and business model (e.g., independent ski area operators versus ski conglomerates). This, combined with the highly competitive nature of the ski industry, suggests that an unplanned, market-based contraction of the industry, a continuation of the historical trend in North America, represents its likely future in an era of climate change. Hamilton et al. (2003) speculate that climate change during the latter half of the 20th-century partially contributed to the loss of hundreds of ski areas in the New England region of the US. The projected warming trend over the first five decades of the 21st century is also likely to have a similar or perhaps more pronounced affect in this region and other ski regions of North America and internationally.

Individual ski areas that are better climate adapted and with greater adaptive capacity (as defined by Yohe and Tol (2002)) than their competitors will be the survivors in an era of climate change. The authors hypothesize that ski areas with greater adaptive capacity are characterized by the following: they have the potential to expand into higher elevation terrain where exposure to climate change is lower and snowmaking capabilities enhanced; they have capital to develop efficient and extensive snowmaking systems; they have the capacity to expand water supply for increased snowmaking; they have the capacity to further diversify resort operations (multiple winter activities and four-season operation); they are part of a larger company or regionally diversified ski conglomerate that could provide financial or human-resource support during poor business conditions; they are located in jurisdictions with less land use restrictions (e.g., outside of national parks or in states/provinces where skiing makes a large contribution to the economy) and have positive relationships with host communities, both of which may reduce constraints to adaptation. Although projected climate change would contribute to the demise of poorly adapted ski companies, it is likely to selectively advantage those that remain. Assuming skier/rider demand remains relatively stable, then ski areas that remain could be in a position to take advantage of a climatically altered business environment, gaining market share (through lost competition) and potentially maintaining or even improving economic performance despite reduced ski seasons and higher operating costs (i.e., snowmaking).

Conclusion

As awareness of the potential impacts of climate change increases among ski area operators and their investors, it is likely that plans will be set in place to reduce the risks and take advantage of any strategic opportunities posed by a changed climate. Determining the potential 'winners and losers' in the ski industry, at both the individual ski area and destination level, remains an important task for future climate change vulnerability research. Studies that only modeled future natural snow conditions and did not take snowmaking into account have likely overestimated the potential damages and over-generalized impacts among individual ski businesses.

The next generation of climate change studies on the international ski industry must consider supply-side adaptation in order to better understand the sustainability of the winter sports tourism product. Minimally, future studies need to identify which of the range of adaptation options outlined in this paper are available to the ski areas being examined and discuss how adaptation would alter the projected impacts. Methodologies have been developed so that snowmaking should be incorporated into ski season analysis (see Scott et al. 2003, 2006) in the future. Accounting for the adaptive capacity of ski areas with different business models will be a greater methodological challenge, but is required in order to be able to answer key questions about changes in the competitive relationships in regional winter sports tourism marketplaces (and related real estate developments) and the future of the major skiing destinations.

The other critical knowledge gap which must be addressed with regard to climate change adaptation in the winter sports tourism industry is demand-side adaptation. Regional studies of the response of skiers to previous climate change analogue events and their stated responses to hypothetical climate change scenarios are required. Only when supply- and demand-side adaptation are incorporated into vulnerability assessments will the complexity of local and regional economic impacts of climate change on winter sports tourism be more accurately understood.

Acknowledgements The authors are grateful to the Government of Canada's Climate Change Action Fund—Impacts and Adaptation Programme (Project A715) for partial financial support of this research and to all of the stakeholders from the ski industry in Canada and the US that have shared their time and insights on a wide range of issues related to their industry. The support of Canada Research Chair Program (corresponding author) by the Government of Canada was also essential to this research.

References

Adger W, Arnell N, Tompkins E (2005) Adapting to climate change: perspectives across scales. Global Environmental Change 15:75–76

ACACIA (2000) Tourism and recreation. In: Parry M (ed) Assessment of potential effects and adaptations for climate change in Europe. Jackson Environment Institute, University of East Anglia, Norwich

Best A (2003) Is it getting hot in here? Ski Area Management May:57–76

Becken S (2005) Harmonising climate change adaptation and mitigation: the case of tourist resorts in Fiji. Global Environ Change Human Policy Dimensions 15(4):381–393

Behringer J, Bürki R, Fuhrer J (2000) Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture. Int Assess 1:331–338

Bloomberg News (2004) Operator betting on natural instead of snow insurance. Financial Post 12 January: FP5

Braun O, Lohman M, Maksimovic O et al (1999) Potential impact of climate change on preference for tourism destinations: a psychological pilot study. Climate Res 11:247–254

Breiling M, Charamza P (1999) The impact of global warming on winter tourism and skiing: a regionalized model for Austrian snow conditions. Regional Environ Change 1(1):4–14

Bürki R (2000) Klimaaenderung und tourismus im Alpenraum - anpassungsprozesse von thouristen und tourismusverantwortlichen in der region Ob- und Nidwalden. Dissertation, University of Zurich

Canadian Ski Council (2004) Canadian ski & snowboard industry. http://www.canadianskicouncil.org/site/images/content/pdfs/Facts%20%20Stats%202004%20-%20all%20final.pdf. Accessed 25 August 2005

Casola J, Kay J, Snover A, et al (2005) Climate impacts on Washington's hydropower, water supply, forests, fish and agriculture. Centre for Science and the Earth System. University of Washington, Seattle

Cockerell N (1994) Market segments: the international ski market in Europe. EIU Travel Tourism Analyst 3:34–55

de Freitas C (2003) Tourism climatology: evaluating environmental information for decision making and business planning in the recreation and tourism sector. Int J Biometeorol 4:45–54

de Loe R, Kreutzwiser R, Moraru L (2001) Adaptation options for the near term: climate change and the Canadian water sector. Global Environmental Change 11:232–245

Efron S (2005) Schussing on slush (or worse). Globe and Mail 9 March:T1, T4

Elsasser H, Bürki R (2002) Climate change as a threat to tourism in the Alps. Climate Res 20:253–257

Elsasser H, Messerli P (2001) The vulnerability of the snow industry in the Swiss Alps. Mountain Res Develop 21(4):335–339

Erickson J (2005) Changes in the air, part 3: bleak forecast for the ski industry. Rocky Mountain News 19 March. http://rockymountainnews.com. Accessed 25 August 2005

Faust J (1998) Cloaks of secrecy surround activist group Earth Liberation. http://more.abc-news.go.com/sections/us/DailyNews/elf981022.html. Accessed 22 September 2004

Fukuskima T, Kureha M, Ozaki N et al (2003) Influences of air temperature change on leisure industries: case study on ski activities. Mitigation Adapt Strategies Climate Change 7:173–189

Galloway R (1988) The potential impact of climate change on Australian ski fields. In: Pearman G (ed) Greenhouse: planning for climatic change. CSIRO, Melbourne

Gomez-Martin MB (2005) Weather, climate and tourism – a geographical perspective. Ann Tourism Res 32(3):571–591

Goodman J (2005) Battered ski area sweating for snowfall. Seattle Times 27 October

Gossling S, Hall CM (2006) Conclusion: wake up this is serious. In: Gossling S, Hall C M (eds) Tourism and global environmental change. Routledge, London

Greenwood J (2004) Investors wait since 1991 on ski resort plan: regulatory faceoff. Financial Post 12 January: FP1, FP5

Hamilton L, Rohall D, Brown B et al (2003) Warming winters and New Hampshire's lost ski areas: an integrated case study. Int J Sociol Soc Policy 23(10):52–73

Hamilton J, Maddison D, Tol RSJ (2005a) Climate change and international tourism: a simulation study. Global Environ Change 15:253–266

Hamilton J, Maddison D, Tol RSJ (2005b) Effects of climate change on international tourism. Climate Res 29:245–254

Hayhoe K, Cayan D, Field C et al (2004) Emission pathways, climate change, and impacts on California. Proc Natl Acad Sci 101(34):12422–12427

Hennessy K, Whetton P, Smith I et al (2003) The impact of climate change on snow conditions in mainland Australia. CSIRO Atmospheric Research, Aspendale, Australia

Horrocks T (2001) Cloud seeding = powder days? http:www.skinet.com/skinet/news/article/0.12855.323635.00.html. Accessed 24 January 2006

Innovest Strategic Value Advisors (2003) Carbon finance and the global equity markets. Carbon Disclosure Project, Innovest Strategic Value Advisors, London

Intergovernmental Panel on Climate Change (IPCC) (1996) Climate change 1995: impacts, adaptations and mitigation of climate change. Scientific-Technical Analyses. United Nations Intergovernmental Panel on Climate Change, Geneva

Intergovernmental Panel on Climate Change (IPCC) (2001a) Climate change 2001: synthesis report. Summary for policy makers. Third Assessment Report. United Nations Intergovernmental Panel on Climate Change, Geneva

Intergovernmental Panel on Climate Change (IPCC) (2001b) Climate change 2001: impacts, adaptation and vulnerability. Third Assessment Report. United Nations Intergovernmental Panel on Climate Change, Geneva

Jahn G (2005) Glacial cover-up won't stop global warming. Associated Press 17 July. http: abcnews.go.com/International/wireStory?id=947283&CMP=OTC-RSSFeeds0312. Accessed 26 January 2006

Jones B, Scott D (2006a) Climate change, seasonality and visitation to Canada's national parks. J Parks Recreat Administ 24(2):42–62

Jones B, Scott D (2006b) Implications of climate change for visitation to Ontario's provincial parks. Leisure 30(1): 233–261

Keates L, (2000) Flake out: ski season off to slow start. The Wall Street J 7 January W7

King S (2005) A frosty relationship. Ski Area Manage 44(1):12

Klein R (2003) Adaptation to climate variability and change: what is optimal and appropriate? In: Giupponi C, Schechter M (eds) Climate change in the Mediterranean: socio-economic perspectives of impacts, vulnerability and adaptation. Edward Elgar, Cheltenham, UK

König U (1998) Tourism in a warmer world: implications of climate change due to enhanced greenhouse effect for the ski industry in the Australian Alps. Wirtschaftsgeographie und Raumplanung 28 University of Zurich

König U, Abegg B (1997) Impacts of climate change on tourism in the Swiss Alps. J Sustainable Tourism 5(1):46–58

KPMG Consulting (2000) Victoria alpine resorts – economic significance study 2000. State of Victoria, Australia. http://www.arcc.vic.gov.au/documents/Alpine%20Economic%202000%20Full%20report%20(1356b).pdf. Accessed 26 January 2006

Lamothe and Périard Consultants (1988) Implications of climate change for downhill skiing in Quebec. Climate Change Digest 88–03. Environment Canada, Ottawa

Lazard A (2002) Ski winter: world flat. Ski Area Manage September: 24–27

Leary NA (1999) A framework for benefit–cost analysis of adaptation to climate change and climate variability. Mitigation Adapt Strategies Global Change 4(3–4):307–318

Lipski S, McBoyle G (1991) The impact of global warming on downhill skiing in Michigan. East Lakes Geographer 26: 37–51

Lise W, Tol RSJ (2002) Impact of climate on tourism demand. Climate Change 55(4):439–449

Lowe R (2003) Preparing the built environment for climate change. Building Res Inform 31(3–4):195–199

Maddison D (2001) In search of warmer climates? The impact of climate change on flows of British tourists. Climate Change 49:193–208

Maloney T (2005) Frustrated ambition. Ave Magazine December:101–106

McBoyle G, Wall G (1987) The impact of CO_2 induced warming on downhill skiing in the Laurentians. Cahiers de géographie du Québec 31(82):39–50

McBoyle G, Wall G (1992) Great Lakes skiing and climate change. In: Gill A, Hartmann R (eds) Mountain resort development. Centre for Tourism Policy and Research, Simon Fraser University, Burnaby, BC, Canada

National Research Council (2003) Critical issues in weather modification research. Committee on the Status and Future Directions in US Weather Modification Research and Operations. National Research Council, Washington, DC

National Ski Areas Association (NSAA) (2004) http://www.nsaa.org. Accessed 1 September 2004

National Ski Areas Association (NSAA) (2006) http:www.nsaa.org/nsaa/2005/04–05-sa-number-history. pdf. Accessed 11 January 2006

Raksakulthai V (2003) Climate change impacts and adaptation for tourism in Phuket, Thailand. Asian Disaster Preparedness Centre, Pathumthai, Thailand

Reuters (2004) Climate change seen climbing agendas – investor group. 18 May

Richardson R, Loomis J (2004) Adaptive recreation planning and climate change: a contingent visitation approach. Ecol Econ 50:83–99

Scott D (2005) Global environmental change and mountain tourism. In: Gossling S, Hall CM (eds) Tourism and global environmental change. Routledge, London

Scott D, Jones B (2005) Climate change and Banff: implications for tourism and recreation - executive summary. Banff, Alberta, Canada

Scott D, Jones B (2006) The impact of climate change on golf participation in the Greater Toronto Area (GTA): a case study. J Leisure Res 38(3):363–380

Scott D, Jones B, Lemieux C et al (2002) The vulnerability of winter recreation to climate change in Ontario's Lakelands tourism region. Department of Geography Publication Series Occasional Paper 18, University of Waterloo, Waterloo, Ontario, Canada

Scott D, McBoyle G, Mills B (2003) Climate change and the skiing industry in Southern Ontario (Canada): exploring the importance of snowmaking as a technical adaptation. Climate Res 23:171–181

Scott D, Wall G, McBoyle G (2005a) The evolution of the climate change issue in the tourism sector. In: Hall CM, Higham J (eds) Tourism, recreation and climate change. Channelview Press, London

Scott D, Jones B, Abi Khaled H (2005b) Climate change: a long-term strategic issue for the NCC. Implications for recreation-tourism business lines. Report prepared for the National Capital Commission, Department of Geography, University of Waterloo, Waterloo, Ontario, Canada

Scott D, McBoyle G, Mills B et al (2006) Climate change and the sustainability of ski-based tourism in eastern North America; a reassessment. J Sustainable Tourism 14(4):376–398
Simmons P (2005) Swiss plan to wrap up their glaciers. The Times 30 March: 66
Smit B, Skinner M (2002) Adaptation options in agriculture to climate change: a typology. Mitigation Adapt Strategies Global Change 7:85–114
Smit B, Burton I, Klein R et al (2000) An anatomy of adaptation to climate change and variability. Climate Change 45(1):233–251
Statistics Canada (2005) Table 361–0002 – summary statistics for arts, entertainment and recreation by North American industry classification system (annual – skiing facilities). http://cansim2.statscan.ca/cgi-win/CNSMCGI.exe. Accessed 11 July 2005
Stehr N, von Storch H (2005) Introduction to papers on mitigation and adaptation strategies for climate change: protecting nature from society or protecting society from nature?. Environ Sci Policy 8:537–540
The Economist (1998) Winter wonderlands. The Economist 31 January
The Wall Street Journal (2005) Investors request data on company emissions. The Wall Street Journal 2 February
Thorne P (2006) World snowdomes report 2006. http://www.snow365.com:9673/snow365. Accessed 11 January 2006
Tommasini D (2003) Personal communication. North Atlantic Regional Studies (NORS), University of Roskilde, Roskilde, Denmark
United States National Assessment Team (2000) Climate change impacts on the United States: the potential consequences of climate variability and change. Cambridge University Press, New York
United Nations Environment Programme (UNEP) (2003) Climate change and winter sports: environmental and economical threats. United Nations Environment Programme, Geneva, Switzerland. www.unep.org/sport_env/Documents/torinobuerki.doc. Accessed 26 January 2006
Uyarra M, Cote I, Gill J et al (2005) Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states. Environ Conserv 32(1):11–19
Wall G (1992) Tourism alternatives in an era of global climate change. In: Smith V, Eadington W (eds) Tourism alternatives. University of Pennsylvania, Philadelphia
Wall G, Badke C (1994) Tourism and climate change: an international perspective. J Sustainable Tourism 2(4):193–203
Wickers D (1994) Snow alternative. Sunday Times 27 November: 9
Williams P, Dossa K (1990) British Columbia downhill skier survey 1989–90. The Centre for Tourism Policy and Research, Simon Fraser University, Burnaby, BC, Canada
Wolfsegger C, Gossling S, Scott D (in press) Climate change risk appraisal in the Austrian ski industry. Tourism Rev Int
World Tourism Organization (2003) Climate change and tourism. In: Proceedings of the First International Conference on Climate Change and Tourism. Djerba, 9–11 April 2003
Yohe G, Tol RSJ (2002) Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity. Global Environ Change 12:25–40