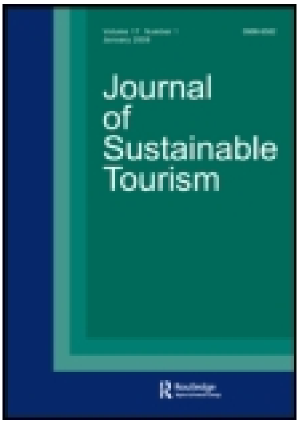

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Changes in demand for tourism with climate change: a case study of visitation patterns to six ski resorts in Australia

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Changes in demand for tourism with climate change: a case study of visitation patterns to six ski resorts in Australia

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Tourism in ski resorts depends on snow cover which is expected to decline with climate change. This paper explores hypotheses about demand side responses to climatic change by analyzing patterns of visitation in recent years with differing snow cover. Snow cover and visitation patterns to six resorts which differ in altitude and size in Victoria, Australia, were compared between a slightly warm and much drier year (2006, +0.6°C and −50% precipitation to longer-term averages) to a more typical year (2007) and to nine earlier years. Snowmaking partly offset declines in natural snow cover in 2006, although there were still fewer days with snow on the ground. The number of visitor days was much lower in 2006 than the previous nine years for the three lowest-altitude resorts (−69%), while it actually increased (+10%) in the highest altitude resort where there were fewer visitors (−17%), but they stayed longer. Snowmaking is already critical for ski resorts in low snow years. With warmer conditions, lower-altitude resorts may not receive enough income due to reduced visitation to offset snowmaking costs, while higher-altitude resorts may have a short-term gain, but become uneconomical in the longer term.

Keywords: climate change; snow tourism; Australian Alps; ski resorts; environmental sustainability

Introduction

Ski resorts are major tourism destinations in many mountain regions. Estimates of the value of the industry worldwide are of the order of $9 billion a year (Scott, 2006). Changes in the climate because of global warming are already occurring in many mountain regions of the world, including higher temperatures, less snow, reductions in glaciers and increases in the size of glacial lakes (Agrawala, 2007; IPCC, 2007). Projected changes for mountain regions include warmer temperatures and changes in precipitation resulting in reduced snow cover which will affect snow-based tourism in ski resorts (Agrawala, 2007; Elsasser & Messerli, 2001; IPCC, 2007).

The Australia ski industry is small compared with Europe and North America, attracting around 1% of the world's ski visitors (König, 1998; Scott, 2006). However, it is an important tourism destination within Australia with an estimated worth of AU$900 million in 2005 (NIEIR, 2006). Nearly all ski tourism occurs in the highest part of the Great Dividing Range in the Australian Alps. The duration of snow cover is short, with 60–70 days of snow cover considered viable (Galloway, 1988) compared with the "100 day" value often used to assess viability in Europe (Abegg, Agrawala, Crick, & de Montfalcon, 2007; König & Abegg,

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1997; Moen & Fredman, 2007) and in North America (Scott, Dawson, & Jones, 2008; Scott, McBoyle, & Minogue, 2007). The vertical drops on ski runs are not long (>300 m, Table 1), the altitude of the resorts is relatively low (∼1595 m, Table 1) compared with those in Europe (Abegg et al., 2007), powder snow is rare and the snow is often not very deep (Galloway, 1988; König, 1998; Sanecki, Green, Wood, & Lindenmayer, 2006).

There is some evidence that the climate of the Australian Alps is already changing including 30% reduced overall snow cover (Green, 2010; Green & Pickering, 2002, 2009; Hennessy et al., 2008), and 40% in spring (Nicholls, 2005). Projections of future climate change indicate there is likely to be higher temperatures and decreased precipitation resulting in reduced snow cover (Hennessy et al., 2008, Table 1). Temperatures in the alpine and subalpine areas of mainland Australia are projected to rise by +1°C (high-emission scenario) by 2020 from 1990 values (Hennessy et al., 2008). This change in temperature combined with projected decreases in precipitation could affect snow cover. The total area of land in the Australian Alps that receives at least 60 days of snow cover a year is projected to decrease by 60.3% (high-emission scenarios by 2020, Hennessy et al., 2008). With potentially greater increases in temperature and likely decreases in precipitation by 2050, the decrease in the area of snow cover is even more dramatic (96.3%, Hennessy et al., 2008). Paralleling changes in the total area of land with snow are reductions in the depth and duration of natural snow cover in ski resorts, with lower altitude resorts experiencing the largest reductions (Hennessy et al., 2008). Under high-emission scenarios the duration of the ski season based on natural snow cover is projected to decline to between 30 and 99 days for all but the highest areas in the Victorian ski resorts (Hennessy et al., 2008).

Climatic change modeling indicates that Australian ski resorts, like many in Europe and North America, will need to increase their use of snowmaking to maintain adequate snow cover in the future (Hennessy et al., 2008). Australian ski resorts already increasingly use snowmaking to provide a base early in the season and even out snow cover (ASAA, 2008; Bicknell & McManus, 2006; Pickering & Buckley, 2010; Pickering & Hill, 2003). The potential for Australian and overseas ski resorts to use snowmaking to offset low-snow years may be affected by environmental and economic constraints including power and water availability (Agrawala, 2007; Hennessy et al., 2008; Pickering & Buckley, 2010; Vanham, De Toffel, Fleischhacker, & Rauch, 2009).

The potential response of skiers to reduced snow cover (demand side response), now and in the future, has been examined in Europe (Behringer, Buerki, & Fuhrer, 2000; König & Abegg, 1997), North America (Dawson, Scott, & McBoyle, 2009; Hamilton, Brown, & Keim, 2007; Scott, 2006), Japan (Fukushima, Kureha, Ozaki, Fujimori, & Harasawa, 2002) and Australia (König, 1998; Pickering, Castley, & Burtt, 2010). This has included surveying skiers to assess their response to projected changes in climate in the Swiss Alps (Behringer et al., 2000) and in Australia (König, 1998; Pickering et al., 2010), and to different destination attributes including sufficient natural snow in Austria (Unbehaun, Probstl, & Haider, 2008). It has also included modeling relationships between current patterns of visitation and climate in the Swiss Alps (König & Abegg, 1997), Japan (Fukushima et al., 2002), New England, Ontario and Quebec (Scott, 2006), just New England (Hamilton et al., 2007), Michigan (Shih, Nicholls, & Holecke, 2009) and the northeastern USA (Dawson et al., 2009) in North America. One approach is to compare visitation in winter(s) considered typical of current conditions, with that for warmer year(s) (Dawson et al., 2009; König & Abegg, 1997; Scott, 2006). This analogue approach can examine the potential behavioral responses of skiers to changes in snow cover, and how successful current snowmaking may be at attracting visitors when there is little natural snow (Dawson et al., 2009; Hamilton et al., 2007; Scott, 2006). It may indicate if skiers respond to warmer conditions by reducing

Table 1. Characteristics of the six ski resorts in Victoria, Australia. Information from NIEIR 2006, updated to 2008 values from individual resort websites. Duration of the ski season (in days) is for the highest altitude ski slope given in Hennessy et al. (2008) under current conditions, and projected in 2020 and 2050 under a high-emission scenario.

	Altitude lift point		Facilities				Snowmaking			Duration of ski season		
Ski resort	Highest	Lowest	Number lifts	Number beds	Ski trails (km)	Downhill ski area (ha)	Area (ha)	No. snow groomers	No. snow guns	Current	2020	2050
Mt Hotham	1845	1450	13	3500	35	320	25	9	75	129	97	21
Mt Buller	1790	1390	25	7000	9	180	70	15	81	108	70	7
Falls Creek	1780	1500	15	4200	20	451	100	NA	210	125	92	18
Mt Baw Baw	1560	1450	7	700	10	35	10	NA	10	80	32	1
Lake Mountain	1480*		0	0	4	0	4		6	74	30	1
Mount Stirling	1234*		0	0	75	0	0	0	0			
Total			**60**	**15,400**	**153**	**386**	**209**		**382**			

*Location of facilities at resort, as no lifts.

the duration/frequency of their skiing, changing where they ski and/or changing when they ski (Hamilton et al., 2007; Pickering et al., 2010; Scott et al., 2008).

To assess potential demand side responses to low levels of natural snow in Australia, data on snow conditions and visitation was obtained for six ski resorts in Victoria, Australia, for a very low snow season (2006), and the following year which had more typical snow cover (2007), along with averages for the previous nine years (1997–2005) (ARCC, 2007, 2008). These years were selected because they represent different natural snow conditions and because data is publicly available. Also by comparing chronologically close seasons, the effects of supply and demand side factors other than snow depth that could affect visitation are minimized. For example, supply side factors minimized include changes in snowmaking capacity and variation in other facilities and attractions in resorts and demand side factors such as the demographics of the skiing population, and the general economy, all of which can affect visitation to ski resorts (Dawson et al., 2009; Unbehaun et al., 2008).

This paper specifically examines (1) if there are fewer visitors (number of visitors and number of visitor days) to ski resorts in a year with low natural snow, even with snowmaking, (2) if there were any differences in the effect of low snow on visitation between lower-altitude and higher-altitude resorts, (3) if visitors altered how long they stayed in a resort in a year with little natural snow and (4) if there was any potential displacement among ski resorts in a year with little natural snow.

Methods

Ski resorts

Ski tourism in Australia is concentrated in the Australian Alps in south-eastern Australia, with limited opportunities also available in Tasmania (Figure 1, Table 1, NIEIR, 2006). There are 10 resorts currently operating in the Australian Alps, four in New South Wales (NSW) and six in Victoria (NIEIR, 2006). A small family day resort in the Australian Capital Territory, Corin Forest, no longer provides snow-based activities, while the small ski resort at Mt Buffalo in Victoria closed after most of the facilities were damaged during the large scale bushfires in 2003, and is unlikely to open again as a ski tourism destination.

Australian ski resorts currently have a more marginal climate for skiing compared with Europe and North America. For example, there is limited altitudinal range for ski resorts in Australia compared with resorts in North America and some in Europe, with only around a 725 m range between the subalpine zone at around 1500 m and the highest mountain in Australia at 2228 m (Bicknell & McManus, 2006; Green & Osborne, 1994).

Climatic, snow cover and visitation data

Temperature and precipitation data was obtained from the Australian Bureau of Meteorology for the three weather stations located in the Victorian ski resorts of Mt Buller (1790 m), Falls Creek (1780 m) and Mt Hotham (1845 m) (BOM, 2008). This data was used to calculate the average temperatures for the year, for winter (1 June–30 August) and the end of the ski season (September) for 2006, 2007 and longer-term averages (1990–2008 for Falls Creek, 1985–2008 for Mt Buller and 1990–2008 for Mt Hotham). The time periods used for the longer-term averages were determined by the availability of consistent records for each weather station. Longer-term climatic datasets are limited in the Australian Alps particularly from weather stations in ski resorts (Hennessy et al., 2008), so longer-term

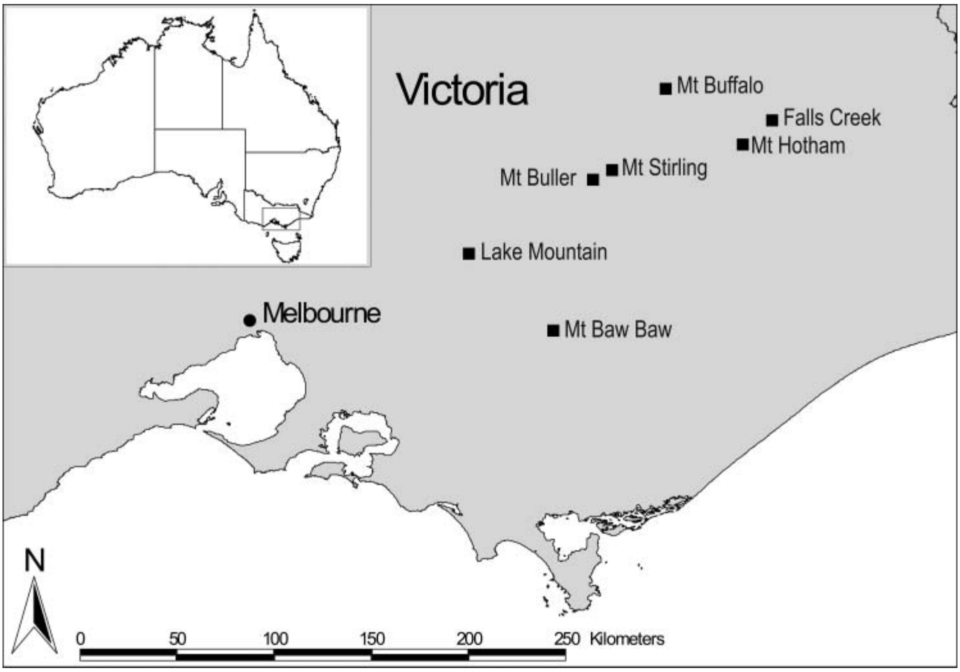

Figure 1. Location of the six ski resorts in Victoria, Australia.

baselines such as 1961–1990 or 1971–2000 used in other studies could not be used here (Dawson et al., 2009).

Publicly available data for individual ski resorts on snow cover, visitation and financial information is also limited in Australia. For example, for the privately owned ski resorts in NSW such data is often considered commercially confidential and is difficult to obtain (Pickering & Buckley, 2010). For Victoria, the Alpine Resorts Co-coordinating Council, a government body, publishes “End of Season Reports” the following year on their website which include data on snow depth for individual Victorian ski resorts (ARCC, 2007, 2008). However, they have only been doing it from the 2006 ski season to the present. For the 2006 season, the report included graphs of natural snow cover from 11 June to 8 October in 2006 and averages values in the period 1997–2005 for each of the ski resorts in Victoria, while for the 2007 season it included snow cover from 10 June to 7 October 2007. From these snow cover figures, five measures of snow were derived for the 2006 season, the 2007 season and the average values for the period 1997–2005: the number of days (1) with any snow, (2) with >20 cm of snow and (3) with >30 cm of snow, the maximum depth of snow during the season (in cm), and metre days of snow (sum of the area under the curve in the graphs of snow depth). The reports only provide information on snow cover between fixed dates, setting an upper limit of ∼116 days for the duration of snow cover in a given year. The snow depth values used here reflect thresholds relevant to ski resort operators in Australia (Hennessy et al., 2008) but are slightly lower than thresholds used for resorts in North America (Scott, Boyle, & Mills, 2003).

Longer-term data on visitation to individual Victorian ski resorts is available in the Appendix to the “End of Winter Reports”, including the number of visitors per ski season (sum of the number of visitors per day to a resort in the ski season based on ticket sales and survey data) (1980 to present) and visitor days per ski season (visitor numbers per day

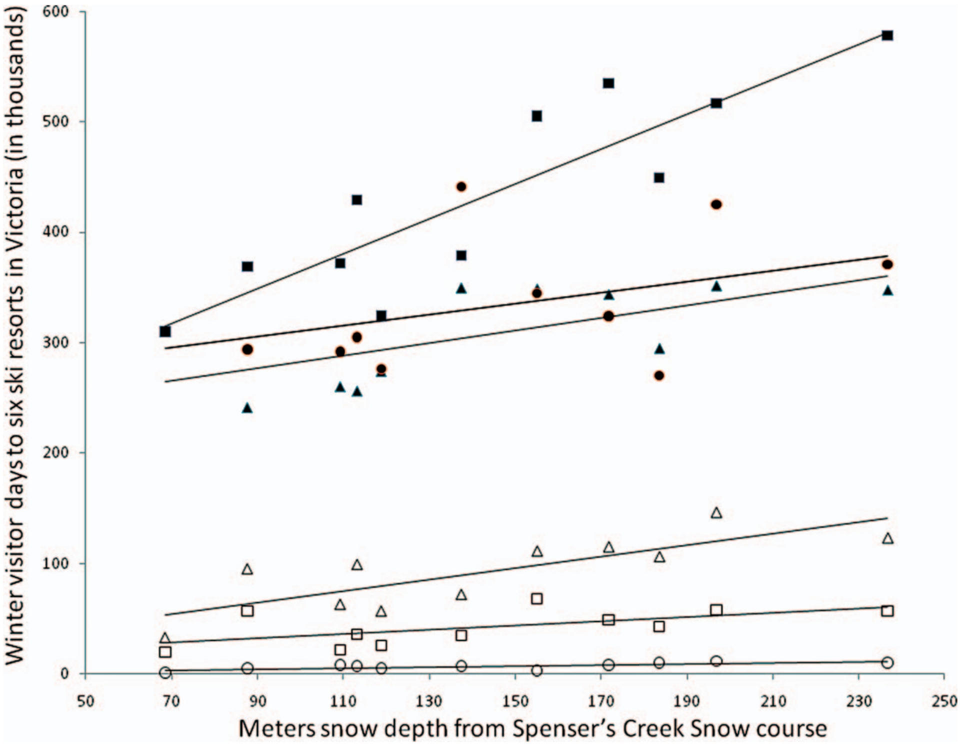

Figure 2. Relationship between visitation (visitor days = number of visitors per day summed for season) and natural snow cover (metre days = depth of snow multiplied by the numbers of days at that depth summed to give a single figure for each year) for the six ski resorts in Victoria. Mt Baw Baw = clear square, Lake Mountain = clear triangle, Mt Stirling = clear circle, Mt Hotham = dark triangle, Falls Creek = dark circle, Mt Buller = dark square, snow cover = 68.5 metre days in 2006 (left most values) and 155.1 metre days in 2007 (middle values).

× number of days per season) (1985 to present) (ARCC, 2007, 2008). However, because average snow cover values in resorts were only available for 1997–2005, the same interval was used for average visitation data for resorts. To calculate the average duration of a visit per resort per season, the number of visitor days was divided by the number of visitors.

To determine whether there was a relationship between actual visitation to each resort and natural snow depth, linear regressions were performed on visitor days (1997–2007 data) against snow cover (metre days = depth of snow multiplied by the numbers of days at that depth summed to give a single figure for each year). Snow cover data was from the Spencer's Creek Snow Course (1830 m) as it is the most comprehensive and longest continuous measure of snow depth available for the Australian Alps; it has been used previously in modeling changes in snow cover (Green & Pickering, 2002, 2009; Hennessy et al., 2008), and because data for snow cover in all of the six Victorian resorts was not available prior to 2006 in the "End of Winter Reports".

Results

Ski resorts in Victoria

The six ski resorts vary in natural snow cover, area of snowmaking, altitude, facilities, duration of the ski season and visitation patterns (Table 1, Figure 2). There are three low-altitude resorts: Mt Stirling, Lake Mountain and Mt Baw Baw. These resorts are orientated towards family day visitation. Mt Stirling and Lake Mountain are cross country and "snow play destinations" that are considered important for introducing tourists to snow-based activities where no accommodation is provided on site. Mt Baw Baw has snow play, cross country and downhill skiing facilities and provides some accommodation on site.

The three larger- and higher-altitude ski resorts, Mt Hotham, Mt Buller and Falls Creek, have extensive downhill skiing facilities including lifts and accommodation. They also make use of snowmaking (209 ha in total, 366 snow guns, ~22% of total area available for downhill skiing). These three resorts account for 77% of all visitors to the Victorian ski resorts (Figure 2). Visitors tend to stay for one more night at these resorts (average 2.12 days), resulting in a greater number of visitor days (86.5% of total visitor days).

The amount of snow and hence the ski season in Australia is relatively short. The average duration from 1997 to 2005 of 30 cm of natural snow cover in the six resorts is only 66 days, ranging among resorts from 4 to 107 days (Table 2). The maximum snow depth is also fairly low, ranging among resorts from 46 to 128 cm, with an average of only 90 cm for 1997–2005. A mean snow season of 60–70 days is considered the minimum for viable skiing in Australia (Galloway, 1988; Hennessy et al., 2008).

Temperature and snow cover in 2006 compared with 2007 and long-term average

Conditions in 2006 were slightly warmer, with annual average temperatures 0.6°C above the long-term averages across the three Victorian-resort-based weather stations (Table 3). The average temperatures during winter (June–August) were only slightly higher than average, +0.2°C above the long-term averages, but critically, the temperature in September at the end of the ski season was +1.5°C warmer than the long-term average and +1.4°C warmer than in 2007 (Table 3). Rainfall in 2006 was around half of the longer-term average (653 mm in 2006 vs. 1284 mm for the long-term average for Falls Creek and Mt Hotham), reflecting the extensive drought associated with an El Niño event experienced in south-eastern Australia at that time (BOM, 2008).

The warmer year and, in particular, the warmer spring and much lower precipitation in 2006 had a dramatic effect on natural snow cover (Table 2, Figure 2). From 1997 to 2007 the lowest snow cover at Spenser's Creek snow course was in 2006 (68.5 metre days, left most values in Figure 2), while in 2007 the value was 155.1 metre days (middle values in Figure 2). The total amount of snow (metre days) in 2006 across the six resorts declined by 78% compared with the previous nine-year average and was 80% less than the natural snow cover in 2007. Correspondingly, the duration of the ski season was much shorter. Using a minimum depth of 30 cm of natural snow to calculate the duration of the ski season, values ranged from zero days for four resorts to 35 days for Mt Hotham. Even using a more conservative > 20 cm level of snow cover as "viable" gave values ranging from 0 to 53 days among the six resorts, well below the 60–70 days minimum days of operation considered viable by the ski industry in Australia (Galloway, 1988; Hennessy et al., 2008), or the more traditional minimum 100 days season used overseas (Abegg et al., 2007; Scott et al., 2008).

Although there was extensive use of snowmaking machinery in the higher-altitude resorts, the amount of snow in the snowmaking areas in the Victorian resorts was still only 45% of the previous nine-year average. It extended the duration of the ski season in those areas within the resorts that had snowmaking, particularly for the three larger ski resorts. The difference in the number of days with > 30 cm of snow cover between areas of natural snow and snowmaking within a resort in 2006 was 32 compared with 105 days at Falls Creek, zero compared with 75 days at Mt Buller and 35 compared with 94 days at Mt

Table 2. Snow cover and visitation data for the six ski resorts in Victoria, Australia, over a nine-year average (Av.), and for the 2006 and 2007 seasons (ARCC, 2007, 2008).

	Year	Mt Stirling	Lake Mt	Mt Baw	Falls Creek	Mt Buller	Mt Hotham	Av.
Altitude (m)		1234	1480	1560	1780	1790	1845	
Snow cover								
Metre days natural snow	Av.	34.6	18.3	26.9	93.3	59	94.5	54
	2006	3	1.5	3.6	25.2	10.1	27.8	12
	2007	28.8	18.7	63.5	84.1	66.2	99.6	60
Metre days snowmaking	2006		2.5	11.2	66.7	37.6	61.6	36
	2007		23.9	65.2	111.2	92.4	110.4	81
Days > 1 cm natural snow	Av.	104	110	104	116	105	116	109
	2006	38	30	26	102	73	99	61
	2007	90	72		111	107	107	97
Days > 1 cm snowmaking	2006		56	69	111	101	104	88
	2007		71		111	107	107	99
Days > 20 cm of natural snow	Av.	78	38	59	113	104	108	83
	2006	0	0	0	48	23	53	21
	2007	57	35	81	111	111	110	84
Days > 20 cm snowmaking	2006		0	17	105	94	97	63
	2007		42	90	111	111	110	93
Days > 30 cm natural snow	Av.	57	4	34	107	90	105	66
	2006	0	0	0	32	0	35	11
	2007	46	15	70	97	92	95	69
Days > 30 cm snowmaking	2006		0	8	105	75	94	56
	2007		32	70	101	102	104	82
Max. depth (cm) natural snow	Av.	52	109.6	45.5	128	77.7	127.8	90
	2006	12	50.7	14.8	42.6	27	52.8	33
	2007	69	80		113.5	91.6	139	99
Max. depth (cm) snowmaking	2006		50.7	30.5	79	60	93	63
	2007		80		142	111	147	120
Visitation								
Number of winter visitors	Av.	8.7	107.8	32	151.4	235.7	116.7	109
	2006	1.2	33.3	15.4	104.9	157.1	96	68
	2007	3.5	110.8	50.7	138.5	284.1	138.2	121
Number of visitor days	Av.	9.9	107.8	42.8	336.2	411.3	281.7	198
	2006	1.2	33.3	20	309.7	310.6	310.5	164
	2007	3.5	111.8	68.3	345.2	504.9	349	230
Av. duration of visit (days)	Av.	1.14	1	1.34	2.22	1.75	2.41	1.6
	2006	1	1	1.3	2.95	1.98	3.23	1.9
	2007	1	1.01	1.35	2.49	1.78	2.53	1.7

Note: Metre days is equal to sum of depth of snow per day for whole season. The average metre days are for 1997–2005 of natural snow cover. Average visitor values are for 1997–2005. Visitor days is equal to number of visitors per day summed for season, are in thousands. Duration of snow cover is the number of days with > 1 cm, > 20 cm and > 30 cm snow depth in areas with natural and areas with snowmaking within resorts.

Hotham (Table 2). For the two lower-altitude resorts with snowmaking, it was even more critical. For Lake Mountain and Mt Baw Baw, it meant the difference between no days of snow, and a short to moderate season (32 and 70 days, respectively).

In contrast to 2006, 2007 represented a more typical year with temperatures in winter the same or similar to longer-term averages and spring with only 0.2°C warmer in the Victorian ski resorts (while there was slightly higher precipitation over the whole year, Tables 2 and 3). Natural snow cover was very similar to the average from 1997 to 2005,

Table 3. Temperature data for three weather stations located in ski resorts in the Victorian Alps, Australia. Weather data is average temperatures in degrees, based on data from the Bureau of Meteorology (BOM, 2008). Long-term average data is 1990–2008 for Falls Creek, 1985–2008 for Mt Buller and 1990–2008 for Mt Hotham.

	Year	Falls Creek	Mt Buller	Mt Hotham	Average
Altitude (m)		1780	1790	1845	
Temperatures (°C)					
Annual	Av.	5.9	6.05	4.9	5.6
	2006	6.5	6.7	5.4	6.2
	2007	6.6	7.2	5.5	6.4
Winter	Av.	–0.1	0.2	–1.2	–0.4
	2006	0.2	0.4	–1.1	–0.2
	2007	0.6	0	–1.8	–0.4
September (start spring)	Av.	1.85	2.1	0.95	1.6
	2006	3.47	3.81	2.18	3.2
	2007	2.24	2.11	1.11	1.8
Precipitation annual (mm)	Av.	1217	1473.4	1351.5	1347.3
	2006	494	141.28	812.6	653.3
	2007	1467.8	1784.6	1755.2	1669.2

whether measured as duration of snow cover, metre days of snow or maximum snow depth (Table 2, Figure 2).

Even in a year such as 2007 with average natural snow conditions, snowmaking was of benefit for resorts (Table 2). It extended the ski season in all resorts other than Mt Baw Baw by around 12.6 days, with the lowest-altitude resort with snowmaking (Lake Mountain) gaining the greatest benefit. It increased the average metre days of snow from 60 to 81 and the maximum depth of snow by 21 cm. Snowmaking has environmental impacts, although technological developments have reduced some of issues associated with snowmaking in the past (Del Matto & Scott, 2009; Pickering & Hill, 2003). However, issues to do with water and energy consumption, among others, remain of concern, particularly with increased use of snowmaking such as is occurring in Australia (Pickering & Buckley, 2010).

Visitation in 2006 compared with 2007 and 1997–2005

Despite the success of snowmaking in extending the duration of the ski season, overall visitation was still much lower in 2006 than for the previous nine years (Figure 2). Visitation in 2007 was higher than the average for 1997–2005, with 12,000 extra visitors and 32,000 more visitor days. For the six resorts, there were 38% fewer visitors in 2006 compared with the average for the previous nine years. The impact on visitor days was less, due to visitors staying longer. Visitor days were down 17% on the average for the previous nine years, but the duration of a visit was 32% longer (2.4 days in 2006 compared with 1.8 days for 1997–2005); it is not clear what motivated them to stay longer.

The impact of low natural snow on visitation differed with the altitude of the resort. Low natural snow cover resulted in dramatic declines in visitation for the three lowest-altitude resorts, down 86%–52% of the average number of visitors for the previous nine years. For the higher-altitude resorts, the impact was greatest at Mt Buller (down 24% on averages for visitor days), but there was actually an increase in visitor days at Mt Hotham in 2006 (up 10% on the average for the previous nine years). For the three higher-altitude resorts, visitors stayed longer in 2006 than in the previous nine years (13% in Mt Buller, 33% at

Table 4. Relationship between visitation (visitor days = number of visitors per day summed for season) and natural snow cover from the Spenser's Creek Snow course (metre days = depth of snow multiplied by the numbers of days at that depth summed to give a single figure for each year) for the six ski resorts in Victoria using data from 1997 to 2007.

	F	*p*	*R*-squared	Constant	Slope
All six resorts	23.681	**0.001**	0.725	727	3.401
Mt Hotham	6.723	**0.029**	0.428	226	0.565
Mt Buller	32.166	**>0.001**	0.781	207	1.581
Falls Creek	2.095	0.182	0.189		
Mt Baw Baw	4.968	**0.053**	0.356	15	0.192
Lake Mountain	14.961	**0.004**	0.624	18	0.518
Mount Stirling	11.453	**0.008**	0.560	0.027	0.048

Note: Significant relationships at alpha = 0.10 are in bold.

Falls Creek and 34% in Mt Hotham). However, the actual duration of a visit on average was still short, with visitors to Mt Hotham still only averaging 3.2 days stay in 2006.

Relationship between snow cover and visitation for each resort

The relationship between visitation as measured by visitor days and snow cover was statistically significant for the Victorian resorts overall, and for each resort except Falls Creek (Table 4, Figure 2). The closeness of the significant relationships (R-squared), and hence their predictive power, varied from moderate for Mt Baw Baw, where snow cover explained 36% of the annual variation in visitor days, to high for Mt Buller, where snow cover explained 78% of the variation in visitor days between 1997 and 2007. The slope of the regression, and hence rate at which visitor days increased with increasing snow cover, was greatest for Mt Buller with each extra metre day of snow at the Spenser's Creek Snow course in NSW corresponding to 1581 more visitor days at Mt Buller. In contrast, each extra metre day of snow only resulted in 480 more visitor days at Mt Stirling, although this was still statistically significant.

Discussion

For the Victorian ski resorts, 2006 showed a similar increase in temperature to that projected for 2050 and 2070 under a low-impact scenario (+0.6°C) but below that projected for 2020 under a high-impact scenario (Table 5). As current CO_2 levels and temperatures are at,

Table 5. A comparison of climatic conditions in 2006 with those projected changes in temperature and precipitation under different climate change scenarios.

Source	Scenario	Average temp. (°C)	Change in precipitation (%)
Hennessy et al., 2008	Low impact 2020	+0.2	+0.9
Whetton, 1998	Low impact 2030	+0.3	0
Hennessy et al., 2008	Low impact 2050	+0.6	+2.3
	Actual 2006	+0.6	−48
Whetton, 1998	Low impact 2070	+0.6	0
Hennessy et al., 2008	High impact 2020	+0.1	−8.3
Whetton, 1998	High impact 2030	+1.3	−8.0
Hennessy et al., 2008	High impact 2050	+2.6	−24.0
Whetton, 1998	High impact 2070	+3.4	−20

or above, the high end of projections; high-impact scenarios (such as the A1F1 scenario) are more likely to reflect conditions in the near to midterm (5–20 years) than low-impact scenarios (B1 scenario), at least until there are clear reductions in the release of greenhouse gasses (Garnaut, 2008). Therefore, 2006 could be taken as a less severe analogue to the temperatures projected for 2020. However, 2006 represents a more extreme decline in precipitation than any of the climate change scenarios (decline of $\sim$ 50% in precipitation compared with the average). Therefore it represents a moderate rise in temperature (less than projected by 2020) but in a dry year.

Using analogues to examine the potential effects of climate change on ski resorts

This and at least two other studies used visitation to ski resorts in warm years as analogues for predicted climatic conditions impacts on the supply and demand for ski tourism. Warmer years resulted in reduced natural snow cover, reductions in the duration of the ski season, increased reliance on snowmaking, decreased visitation and increased running costs for ski resorts (Dawson et al., 2009; Scott, 2006). For the Victorian ski resorts, the 2006 warm year resulted in reductions in natural snow cover, increased use of snowmaking, reductions in the duration of the ski season and declines in visitation. These changes in supply and demand for ski tourism in 2006 resulted in either reductions in profits (Mt Hotham ARMB [Alpine Resort Management Board], 2007) or an operating deficit (Falls Creek ARMB, 2007; Mt Baw Baw ARMB, 2007; Mt Buller and Mt Stirling ARMB, 2007) for the Victorian resorts.

Low natural snow cover results in decreased visitation even with snowmaking

Results from this and other studies all found that visitation to ski resorts is related to natural snow cover (Dawson et al., 2009; Hamilton et al., 2007; König & Abegg, 1997; Pickering & Buckley, 2010; Scott, 2006; Unbehaun et al., 2008). They also show that snowmaking can offset some, but not all, of the reductions in visitation that occur in a poor natural snow year (Dawson et al., 2009; Hamilton et al., 2007; Pickering & Buckley, 2010). For example, in the Victorian ski resorts a 78% decrease in natural snow cover (45% in areas with snowmaking) in 2006 resulted in a 38% reduction in visitation compared with the previous nine years.

Snowmaking in 2006 had a greater effect on the duration of the ski season than on the maximum depth of snow and the total amount of snow (metre days) increasing the ski season (>30 cm) from 11 to 56 days. However, snowmaking currently only occurs in parts of the Victorian resorts, resulting in patchy snow cover within the resorts in years of low snow cover. For the three highest/largest resorts in Victoria the area of snowmaking varied from 41% at Mt Buller to 11% at Mt Hotham in 2008. This is a smaller proportion of the area of resort with snowmaking than for many North American ski resorts some of which have up to 98% of area of the resorts with snowmaking (Scott & McBoyle, 2007). In Europe, resorts in some regions have extensive snowmaking facilities with 80% of the areas of the French Alps covered by snowmaking, 50% in Austria and 40–60% in resorts in the Italian Alps (Abegg et al., 2007). In contrast, some resorts in Europe have less extensive snowmaking such as the Swiss Alps with 18–22% (Gonseth, 2008), Switzerland with around 18% and Germany with 11.5% of the area of the resorts covered by snowmaking facilities (Abegg et al., 2007).

The effect of a low natural snow cover differed among the six resorts in Australia, with the three lower altitude resorts only able to open in 2006 because of snowmaking. However, even with snowmaking the three low-altitude resorts had a 69% decline in the number of visitors in 2006 compared with the previous nine years. Skiers in Victoria responded to low levels of natural snow by staying longer at the high-altitude resorts in 2006 than they did on average over the previous nine years. This resulted in Mt Hotham actually increasing the number of visitor days in 2006 over the previous nine-year average. Changes in visitor behavior including staying longer are likely to assist in the economic survival of high-altitude resorts in Australia. However, the future of skiing at lower-altitude resorts in Australia is far more problematic. Although snowmaking allowed the three lowest-altitude resorts in Victoria to open in 2006 there was still a dramatic decline in visitation. Already two "family play" low-altitude resorts in Australia are no longer open for winter skiing, Corrin Forest in the Australian Capital Territory and Mt Buffalo in Victoria. Mt Stirling is still operating but is now combined as a single management unit with Mt Buller.

Survey of visitor intent versus actual visitation patterns

The impact of low natural snow on actual visitation patterns is often less than that indicated from surveys about future responses of skiers to declining snow (Scott, 2006). In surveys of skiers in the Swiss Alps, only 30% intended to ski at the same resort at the same frequency if the next 5 years had very little natural snow (Behringer et al., 2000), while in Australia only 25% would continue to ski in Australia at the same frequency in 1996 (König, 1998). When the Australian survey was repeated recently (Pickering et al., 2010), the number who would keep skiing at the same rate in Australia was only 10%.

Differences in the effect of low snow on visitation as estimated from survey of visitor intent (König, 1988; Pickering et al., 2010) and as seen in actual visitation patterns in climate change analogous years (Dawson et al., 2009; Scott, 2006; this study) may reflect the difference in the impact of one year to a few years of poor snow compared with longer periods of decline such as used in visitor intent surveys (König, 1998; Pickering et al., 2010). It may also reflect differences between the intentions of visitors and what they actually do when faced with low natural snow. It may also reflect differences in the interpretation among skiers of the questions asked about future snow conditions. However, the low values in Australia from both surveys of future visitation patterns with low snow and the actual visitation patterns in years of low snow indicate that skiers may be more likely to substitute other activities for skiing in poor snow years, with skiing conditions in Australia more similar to those in low-altitude resorts than many of the larger high altitude/latitude resorts in Europe and North America.

Further research in Australia and other mountain regions will improve our understanding of visitors responses to changes in natural snow cover and snowmaking. This should include studies examining actual visitation patterns using years of poor snow as analogues of future changes as recommended by Dawson et al. (2009), and surveys using more detailed climate change scenarios (and/or discrete choice experiments) (Unbehaun et al., 2008). Also, there is a need for more detailed modeling of skier's response to temperature, snow depth, snow fall, economic factors, and the effect of holidays and weekends within ski resorts as has recently been conducted in the United States (Hamilton et al., 2007; Shih et al., 2009).

Conclusions

Ski resorts in Australia already rely on snowmaking to offset the impact of low natural snow years. This strategy is partly successful with the duration of ski seasons extended in a poor snow year by snowmaking. For low-altitude ski resorts, it can make the difference between no season and a short season, although visitation is still much lower than in a year with more natural snow. For higher-altitude resorts, snowmaking can also increase the amount of snow and extend the ski season beyond that available with natural snow cover. As a result, the impact of a year with poor natural snow cover is not as great on visitation, with skiers sometimes staying longer, particularly at higher-altitude resorts. However, in the longer term, the environmental and financial viability of relying on snowmaking to keep visitors coming to resorts may make this adaptation to climate change a short-term solution. A careful analysis of the sustainability of increased snowmaking to compensate for the projected decline in natural snow will be critical (Del Matto & Scott, 2009).

There are also wider implications for the regional/national triple bottom line of the sustainable tourism equation. Should ski tourism cease in Australia, there could be transport-related climate change impacts if some current Australian skiers in the future used flights to New Zealand and Japan to continue to pursue their sport (see Pickering et al., 2010, for Australian skier intentions, and Scott, 2011, for a wider discussion of this question). Equally there could be socio-economic impacts for the communities involved in ski tourism, and environmental, ecological and social issues connected to adapting those destinations to non-snow-related activities.

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