Effects of Climate Change on Alpine Skiing in Sweden

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Climate change has already affected and will continue to affect physical and biological systems in many parts of the world. For example, annual snow cover extent in the northern hemisphere has decreased by about 10% since 1966, and in Sweden, the last decade was wetter and warmer than the preceding 30-year period. These changes will affect many aspects of utilisation patterns that are dependent on the physical environment, such as alpine winter tourism. In this paper, we discuss the future development of the downhill skiing industry in Sweden. We first review trends in alpine winter tourism in relation to climate change together with regional projections of climate change. Secondly, we examine trends in climate parameters relevant to alpine winter tourism in Sweden during the last 30 years. Thirdly, we take these parameters, together with regional projections of climate change, and predict effects on the number of skiing days in order to estimate the monetary loss for the skiing industry in Sweden. The analyses show predicted losses that are larger than current ski-ticket sales. Adaptation strategies such as the development of year-round tourist activities should be developed as soon as possible.

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Introduction

Climate change, both from natural and anthropogenic causes, has already affected and will continue to affect physical and biological systems in many parts of the world. For example, satellite images show that the annual snow cover extent in the northern hemisphere has decreased by about 10% since 1966 (Folland *et al.*, 2001: 124), and the last decade (1991–2000) was wetter and warmer than the preceding 30-year period in Sweden (Räisänen & Alexandersson, 2003). These changes will affect many aspects of human activities that are dependent on the physical environment, such as agriculture, forestry, water management and tourism.

Numerous studies have documented (e.g. Fukushima *et al.*, 2002; Giles & Perry, 1998; Hamilton *et al.*, 2005; Richardson & Loomis, 2004; Scott *et al.*, 2002)

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or discussed potential effects of climate change on tourism and outdoor recreation (e.g. Ewert, 1991; Harrison *et al.*, 1999; Koenig & Abegg, 1997; Maddison, 2001; Todd, 2003; Wall & Badke, 1994). Mendelsohn and Markowski (1999) argue that future climate change is expected to affect outdoor recreation in three ways: (1) the availability of recreation opportunities through longer summer seasons and shorter winter seasons; (2) the overall comfort and enjoyment of recreation activities; and (3) the quality of the recreation experience. Such changes will produce both winners and losers as different types of outdoor recreation activities require different climatic conditions. For instance, both Loomis and Crespi (1999) and Mendelsohn and Markowski (1999) suggest that climate change will have a positive impact on boating, fishing and golfing and a negative impact on camping, hunting, skiing and wildlife viewing. These results are of course generalisations that might be valid at an aggregate level, while one would expect large regional and local variations among the different recreation activities.

The public good characteristic of climate change poses a particularly difficult challenge for economic and political institutions. It implies that the scarcity of an 'unchanged climate' is not reflected in rising prices and is not automatically rationed to the highest valued users. Further, emission abatement – which is the production of the public good 'unchanged climate' – is conducted independently in various parts of the world (Chichilnisky & Heal, 1993). Climate can thus, rather be considered a privately produced public good, and research on the economics of global warming has to a large extent focused on policy issues and risk assessments (OECD, 1994; Tietenberg, 1997). However, in order to develop efficient policies, inputs from monetary assessments of climate change impacts are necessary. Such economic measures include both direct economic impacts to the economy as well as benefits to the participants (consumer surplus). For example, Scott *et al.* (2002) used expenditure data to provide estimates of the potential economic impacts from climate change on alpine skiing in eastern Canada, while Richardson and Loomis (2005) studied the effects of weather on willingness to pay to visit Rocky Mountain National Park. Some of the pioneering attempts to put an economic value on climate change impacts to tourism and outdoor recreation include Cline (1992), Frankhauser and Pearce (1994), Loomis and Crespi (1999), Meier (1998), and Mendelson and Markowski (1999). For example, Meier (1998) estimated the cost of climate change for the year-round tourism sector in Switzerland at USD 1.1–1.4 billion by the year 2050.

Tourism based on downhill skiing is in several ways dependent on both natural features (terrain, altitude, vertical drop, etc) and climatic conditions (temperatures, wind, precipitation, etc). Previous research has shown that snow conditions are a key variable for skiers to decide where to ski (Gilbert & Hudson, 2000; Richards, 1996). In a study of factors affecting destination choices of British skiers travelling to Canada, snow conditions and skiing terrain were the two most important features (Godfrey, 1999).

Indications that impacts from future climate change on winter tourism can be substantial is evident from research in different parts of the world. McBoyle and Wall (1991) and Scott *et al.* (2002) studied skiing in the Great Lakes Area and found that ski season length will be reduced by projected increases in temperature and precipitation. Koenig and Abegg (1997) estimated that only 63% of all Swiss ski areas will be snow reliable after a 2°C increase in temperature.

Ski areas at low altitudes are particularly sensitive to this change. Fukushima *et al.* (2002) modelled the relationships between air temperature, precipitation, snow depth and the number of skiers at seven ski areas in Japan. They estimated a 30% drop in the number of skiers under the condition of a 3°C increase in air temperature.

If skiing is to remain economically viable in areas with predicted negative climate trends, strategies may have to be developed to counteract the adverse effects. Locations with reduced snow cover may have to introduce alternative attractions during the winter season to remain attractive (McBoyle & Wall, 1991; Todd, 2003). On the other hand, locations that are predicted to receive a reasonable supply of snow may have localised benefits from the ongoing climate changes and may opt to develop that situation. Several authors have discussed the issues of resource planning and adaptation (e.g. Aall & Hoyer, 2005; Elsasser & Bürki, 2002; Ewert, 1991; Frankhauser *et al.*, 1999; Scott, 2006), and perhaps the most familiar measure in the struggle against snow-deficient winters is artificial snowmaking. The effects of snowmaking as an adaptation strategy have also been quantified by Scott *et al.* (2003 and 2006) in their work on climate change impacts on skiing in eastern Canada. Compared to earlier studies that did not incorporate snowmaking techniques, the reassessment by Scott *et al.* (2006) show significant decreases in the projected ski season reduction under both low and high climate change scenarios.

Most previous research on climate change impacts on downhill skiing have focused on the European Alps (e.g. Elsasser & Messerli, 2001; Koenig & Abegg, 1997) and Eastern North America (e.g. Scott *et al.*, 2002 and 2005a). Given the importance of the ski industry (and skiing as an outdoor recreation activity), it is somewhat surprising that the issue has not been extensively studied in the Scandinavian countries. Aall and Hoyer (2005) discuss how the tourism industry in Norway has adapted to climate change and a recent report from the Finnish Environment Institute (Sievänen *et al.*, 2005) gives an overview of adaptations to climate change for several outdoor recreation activities and nature-based tourism entrepreneurs in Finland. The latter provides an analysis of the effects of climate on participation in downhill skiing based on temperature and snow depth.

The current study is, to our knowledge, the first attempt to model the impact of climate change on downhill skiing in the Swedish mountains. We first review trends in alpine winter tourism in relation to climate change together with regional projections of climate change for Sweden. Secondly, we examine trends in climate parameters relevant to alpine winter tourism during the last 30 years in Sweden for a major ski resort area. Thirdly, we take these parameters, together with regional projections of climate change, and predict effects on the number of skiing days, and finally we estimate the monetary loss for the skiing industry based on predicted changes. The objective of the study is to analyse climate change impact on skiing in a Scandinavian context and bring to light some of the associated economic consequences. The economic measures should be seen as a means of quantifying and comparing estimated climate change parameters based on the current ski industry volume.

Swedish Downhill Skiing

Over the past decades, winter sport tourism has emerged as a major industry in many mountain areas around the world. The current ski market is estimated to include some 70 million skiers worldwide, primarily within Europe, North America and Japan. While skiing continues to grow in regions such as Eastern Europe and Southeast Asia, the markets in Europe and North America have matured and participation levels have stabilised (Hudson, 2003).

Both in terms of number of ski resorts and skier visits, Sweden is among the top ten ski nations in the world. The primary area for downhill skiing in Sweden is the mountain region, bordering Norway between 61 and 68 degrees North, where the peaks reach above the treeline (Figure 1). In comparison with other northern tourist areas, such as northern Canada, the Swedish mountain region features a wider range of services and easier access (Lundgren, 1995).

Downhill skiing is the major tourism activity in the Swedish mountain region. A national survey of mountain tourism has shown that almost one quarter of the adult Swedish population (corresponding to 1.4 million individuals) visited the region at least once in a given year (see Heberlein *et al.*, 2002 for details). Two thirds of all visits took place during winter (December – April), and as many as 80% of the winter tourists participated in downhill skiing. About half of the 740,000 downhill skiers participated only in that activity, while others combined downhill skiing with snowmobiling, cross-country skiing or some other activity. Downhill skiing is also the tourist activity that exhibits the largest growth during the last two decades in the Swedish mountain region. Fredman and Heberlein (2003) compared participation in different mountain tourism activities between 1980–1985 and 1995–2000, and found that participation in downhill skiing has increased from 22 to 34% of the Swedish population (an increase equivalent to 800,000 individuals). Most of the increase in downhill skiing is driven by a few large ski resorts in the southern part of the mountain region which is closer to the populated centers in Sweden, while tourism in the north is stable or declining.

More than 80% of the ski-ticket sales in Sweden take place in the mountain region, while smaller ski areas in the interior north and south of Sweden are of less economic importance. Compared to other groups of visitors to the Swedish mountains, downhill skiers is also the category that has the highest level of expenditures at their destination (Fredman, in press), which makes downhill skiing an activity of large importance for many local economies.

Downhill skiing in the mountain region is characterised by relatively small vertical drops (300–500 metres) at low altitudes (500–1200 m a.s.l.). Most ski areas are open from December to April with a peak season between mid-February to mid-April. Because of the northern location, temperatures can be low but they also allow for skiing at relatively low altitudes compared to other places around the world. In relation to most central European and North American ski areas, skiing in Sweden is less demanding. Partly because of this, skiing is often marketed as a family activity and several resorts are easily accessible by car, train or air travel from Stockholm or other densely populated areas.

For the season 2004/05, the total turnover for the Swedish ski industry was estimated at SEK 900 million (approx. €100 million). Between 10 and 20% of the visitors are snowboarders. The ski industry has followed the same general trend

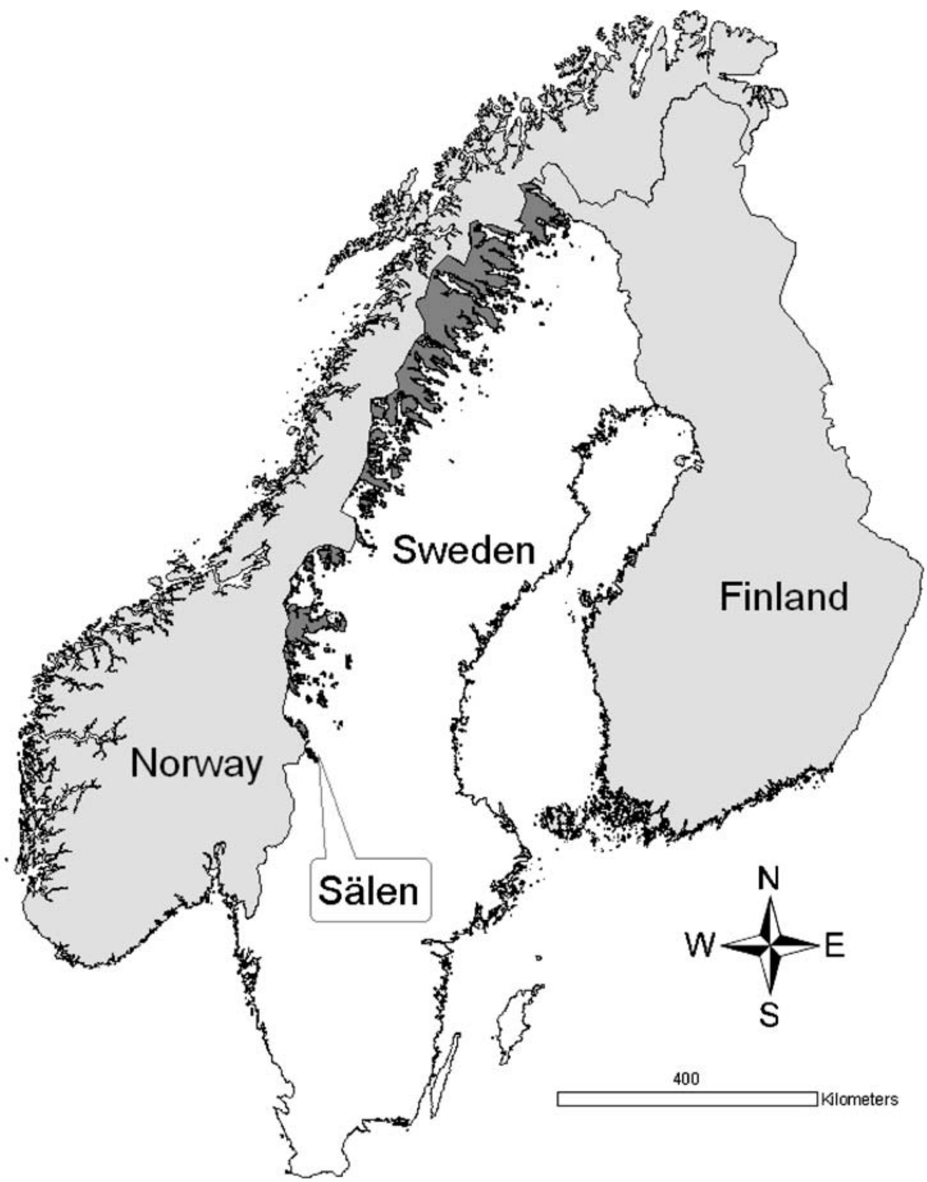

Figure 1 Map of Sweden with alpine areas (i.e. above the treeline) marked in dark grey. The location of the Sälen area is shown

as elsewhere in the world, particularly in the US, of an increased concentration with fewer, but larger, operators. Both investments in ski-lifts and snowmaking equipment and in marketing, involve significant costs. In Sweden, the largest operator (Skistar) has almost 60% of the market share. The current market is primarily domestic (about 90% of the skiers), but effort is being made to increase the international share outside of the Nordic countries (Flagestad & Hope, 2001).

Projections of Regional Climate Change in Sweden

The development of high quality skiing constitutes considerable costs and it is imperative that the resorts can generate income for a relatively long period to cover these costs. The tourism industry thus has a need for climate projections (covering perhaps 10–20 years) to calculate the expected returns on investments. Predicting the future is inherently difficult, and different climate change models will give different projections depending on assumptions on circulation patterns and emission levels. These models should thus be seen as possible future scenarios rather than actual forecasts. However, some general trends can be summarised from the various climate change models.

Räisänen and Alexandersson (2003) presented a forecast for the decade 2001–2010. The forecast concerns Sweden as a whole and not individual locations, but some general trends can be discussed. Their study predicts that winters will be 0.6°C warmer than the mean for the period 1971–2000 (with a probability of 0.73). It is thus reasonable to expect that mean winter temperatures will increase during the near future with effects on the probability of precipitation falling as snow and on snow-melt patterns. Further, their model predicts a 3% increase in precipitation during winter (with a probability of 0.63). It is, thus, possible that increased precipitation will to some extent ameliorate the negative effects of a warmer climate, at least as long as the increased winter temperatures do not increase the probability of winter precipitation falling as rain. However, this will at best only be a short term relief for the tourism industry.

Long term projections of climate change deal with time periods outside the planning horizon of the tourist industry. However, they may be useful in indicating the scale and direction of change in the near future. Projections on global warming for the late 21st century range from +1.4°C to +5.8°C (compared to 1990) depending on the climate model and emission scenario used (Cubasch *et al.*, 2001). This may sound small, but the effects of such an increase in global mean temperature are probably larger than ever experienced by humans. This climate change will not only affect mean temperatures, but also climate variability and the probability of extreme events. For instance, it is likely that extreme cold periods will be more uncommon while extreme heat will be much more common (Cubasch *et al.*, 2001).

Regional climate models for Sweden have been produced by the Swedish Meteorological and Hydrological Institute for the time period 2071–2100 (e.g. Räisänen *et al.*, 2004). They predict that warming will be more pronounced in the winter than in the summer, resulting in a decrease in snow cover. In general, an increase in winter mean temperatures by 4–6°C is expected in northern Sweden, while summer temperatures will only increase by about 2°C. This will lead to a decrease of about two months for the snow-covered period. Winter precipitation will also increase by 30–50% and it is likely that this increase will be mainly through more precipitation on each occasion rather than by longer wet periods. Summer precipitation, on the other hand, will stay unchanged or even decrease slightly. Wind speeds are predicted to increase by 10–20% in the winter in some emission scenarios (Räisänen *et al.*, 2004).

Methods

The data for this paper consists of three parts: (1) climate data for the last 30 years for Sälen (the southernmost, and one of the largest, ski resorts in the Swedish mountains); (2) climate change projections for the period 2070–2100, which together with (1) were used to calculate scenarios of change for Sälen; and (3) data on economic expenditures for skiing trips from the national travel and tourism database. We describe these data sets below.

Climate data for Sälen

We obtained climate data for Sälen (N61.10, E13.16, alt. 360 m a.s.l.; Figure 1) from the Swedish Meteorological and Hydrological Institute. The station has a mean annual temperature of 1.9°C and a mean annual precipitation of 805 mm, for the period 1961–1990. The climate data consisted of daily readings of precipitation, snow depth, minimum, maximum and mean temperatures and the time period covered was from 01.07.1969 until 30.06.2002. We calculated annual cumulative snowfall (in mm) for each winter season. Snowfall was defined as precipitation during days with a minimum temperature below 0°C. We also calculated the length (in days) of the potential skiing season defined as the number of days with >30 cm snow depth (Elsasser & Bürki, 2002; Scott *et al.*, 2003). We further calculated the mean daily temperature (in °C) for the period December to February. Trends in the calculated parameters were estimated with linear regressions.

Temperature trends for winter in Sälen indicate that temperature has been increasing (Figure 2a), with a mean daily temperature increase by about 2°C during the period. This trend will, of course, decrease the skiing season. Precipitation trends, on the other hand, have been more stable (Figure 2b), while average snow depth during the skiing season decreased by 8 cm. Cumulative snowfall measures the total precipitation during the winter, while average snow depth represents more complex relationships between temperature and precipitation resulting from dynamics in snow accumulation, diminution and compaction. Taken together, these trends have impacted the length of the potential skiing season with c. 5 days shorter in Sälen (measured as the number of days with >30 cm snow cover).

Climate change projections

We used our 30-year data series from Sälen, consisting of daily values of precipitation (in mm), maximum and minimum temperatures (in °C), and simulated new time series with a stochastic weather generator (Long Ashton Research Station Weather Generator, LARS-WG, software obtained from Rothamsted Research, UK; http://www.iacr.bbsrc.ac.uk/mas-models/larswg.html). The software can create synthetic weather data for a single site under both current and future climate conditions. Note that the software does not produce weather forecasts, it simply generates time-series of synthetic weather that are statistically identical to the original observations. These time-series can further be forced by introducing predicted climate changes from general circulation models.

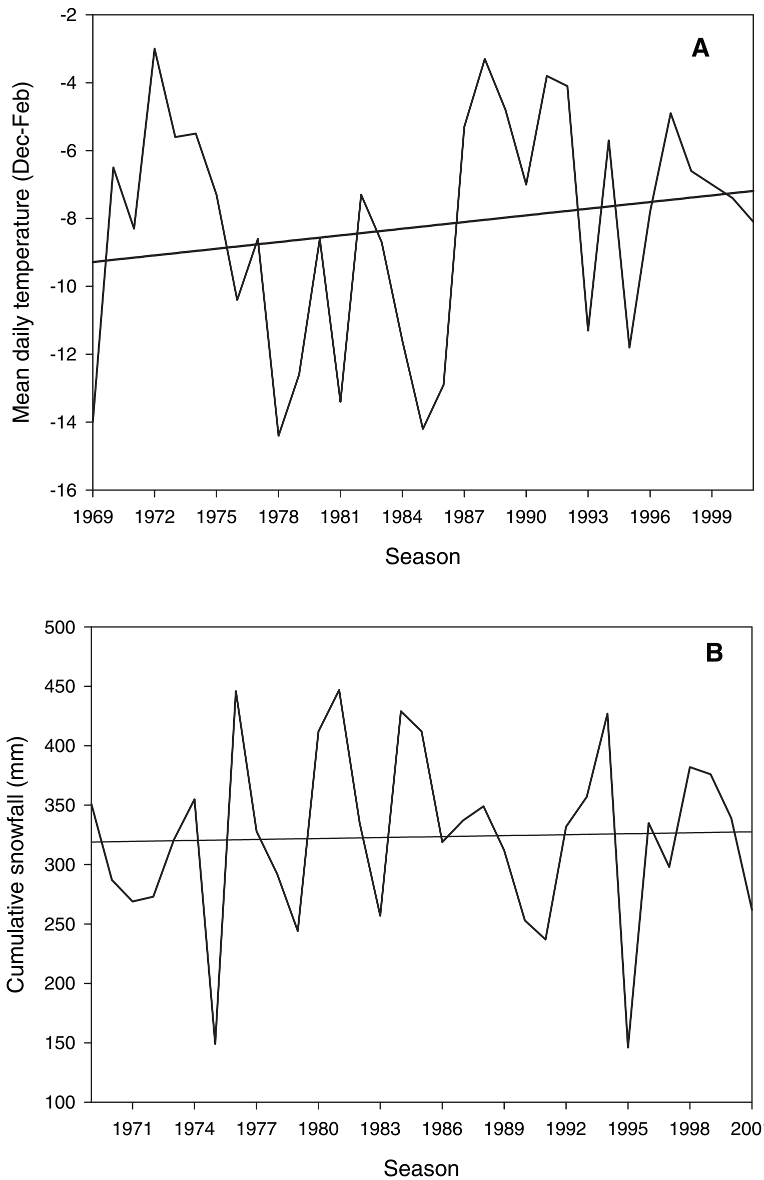

Figure 2 Trends in temperature and snowfall during the last 30 years for the climate station used (Sälen). **A.** Mean daily temperature (in °C) for December to February. **B.** Cumulative snowfall (defined as total amount of precipitation in mm during days where minimum temperature is below 0°C)

Using the LARS-WG software, we determined the statistical characteristics of the 30-year time-series from Sälen and created a synthetic time-series based on these characteristics (see Semenov & Barrow, 1997 and 2002 for details). A validation procedure in the software showed that the model output were statistically indistinguishable from the original time-series and thus could be used for generating time-series for the site (not shown). We used this model to generate 100 synthetic time-series of the current climate and calculated the mean output of these (hereafter called 'current climate'). This was done to produce a climatic baseline that could be forced by the climate change projections. We used the simulated baseline rather than the observed weather parameters to make comparisons with climate change scenarios as similar as possible.

We then extracted projections on changes in temperatures and precipitation for the late 21st century based on regional climate change models (Räisänen *et al.*, 2004, their Figures 8a and 8d). We chose two models, RH-B2 and RE-A2, that encompassed the variations in projections. RE-A2 is based on a general circulation model from the Max-Planck Institute, Germany, and assumes a large and continuous increase in greenhouse gas emissions, while RH-B2 is based on a general circulation model from the Hadley Centre, UK, and assumes a slower increase in emissions. The predicted temperature changes during winter are in the order of 4–6°C for RE-A2 and 2–4°C for RH-B2, while precipitation increases of about 45% for RE-A2 and about 20% for RH-B2 (Figure 3). We used the values from Figure 3 to force the time-series in the LARS-WG software. For each climate scenario, we generated 100 synthetic time-series and calculated the mean output. We calculated the number of days with snowfall (i.e. for days with minimum temperature <0°C) both annually and for each month. Further, we calculated the accumulated snowfall (in mm) annually. We used number of days with snowfall as a proxy for days with >30 cm snow depth which is commonly used to estimate the length of skiing seasons. We, thus, assume that a reduction in the number of days with snowfall is proportional to a reduction in ski season length (the correlation between the number of days with snowfall and days with >30 cm snow depth is significant for the 30-year time-series used for estimating the parameters for the model; $r = 0.48$, $p < 0.01$). While snow depth is a more relevant parameter for the ski resorts, it is also complex process to model where, for instance, snow accumulation, snow layering, compaction, wind redistribution, and snow melt need to be included (e.g. Pomeroy & Brun, 2001). Data to model this process is generally lacking for the area, and any attempt would thus introduce large uncertainties. This is also one of the reasons why we have not included a snowmaking module in the model. Further, while snowmaking can alleviate some of the problems with a shorter winter season, it still requires sub-zero temperatures which will be less common as the winters become warmer. This has been made painfully obvious this winter (2006/07) when many ski resorts in the southern part of the Swedish mountains (including Sälen) were not able to open many slopes even two months into the season. The same reports are also coming in from the Alps (OECD, 2007).

Economic expenditures

We further extracted economic data on downhill skiing from the national travel and tourism database. This database uses random digit dialling among households in Sweden to randomly survey 2,000 individuals (0–74 years old) every month. Questions asked address travel during the preceding month, and include all overnight trips and daytrips at least 100 km away from the respondent's place of residence (Holmström & Junkka, 2003). Expenditure data collected include three categories; expenditures at the destination, expenditures

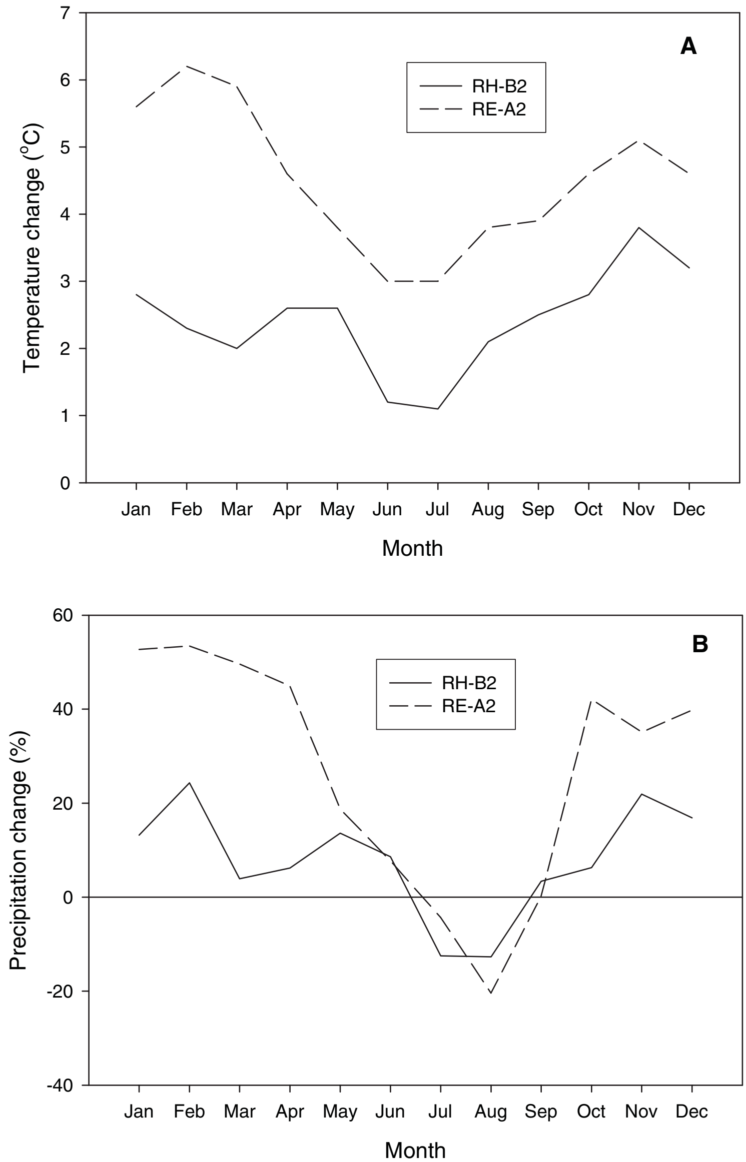

Figure 3 Projections on regional climate changes for the late 21st century based on two general circulation models (see text and Räisänen *et al.*, 2004 for details). **A.** Changes in mean monthly temperatures in °C. **B.** Changes in precipitation (%)

during travel to/from the destination, and expenditures at home that are related to the trip. All three categories are used in this study. Table 1 presents the data projected for the Swedish population in the age range studied (based on a total population of 8,070,000 individuals).

The *average number of trips* include trips to the 15 municipalities in the Swedish mountain region with the primary purpose of downhill skiing for the years 2002

Table 1 Annually average number of domestic downhill ski trips to the Swedish mountain region, average trip expenditure and total expenditures (data from the Swedish national travel and tourism database)[1]

Period	*n*	*Average number of trips*	*Average trip expenditure (SEK[2])*	*Total expenditures (Million SEK[2])*
Nov – Dec	55	128 000 (9.1%)	2 708	346.6 (9.3%)
Jan – Mar	440	987 500 (70.2%)	2 710	2 676.1 (72.2%)
Apr – May	129	290 500 (20.7%)	2 362	686.2 (18.5%)
TOTAL	624	1 406 000		3 708.9

1) Averages for year 2002 and 2003; 2) 1 EUR ≈ 9 SEK

and 2003 divided by 2 (prior to 2002 data on downhill skiing was not collected, only skiing in general). The figures in Table 1 will accordingly represent an average for these two years. The data show that most trips are undertaken from January to March (70%), while about 9% of the downhill ski trips take place in November and December, and about 21% take place in April and May. A similar seasonal pattern occurs also for the *average total expenditures*. However, because of the variations in *average* expenditures, the distribution of *total* expenditures across the subseasons is slightly different (1 EUR ≈ 9 SEK). We estimated the economic impact of climate change on the skiing industry based on the calculated percentage reduction in days with snowfall and the total expenditures for these periods (that corresponds to major skiing seasons in Sweden).

Data provided by the Swedish Ski-area Federation (SLAO) show an average ski-season length of 162 days among the 25 largest ski-areas between 1990/91 and 2001/02. Based on personal communication with representatives for the industry, we estimate that a representative season starts on November 24 and closes on May 4. Consequently, we define the ‘early season’ as November 24 to December 31, the ‘mid season’ as January 1 to March 31 and the ‘late season’ as April 1 to May 4.

Results

Based on the chosen climate change scenarios, we extracted projections on the relative loss of the skiing season length in Sälen for the period 2070–2100. The annual number of days with snowfall decreases strongly in both scenarios (Figure 4a). There is a reduction of 44% in scenario RH-B2 and of 66% in scenario RE-A2. On the other hand, the annual cumulative snowfall increases by 17% and 41%, respectively (Figure 4b). This means that there will be fewer days with snow, but more snow on the days when it is snowing. These patterns are consistent with regional climate change models (Räisänen *et al.*, 2004) showing that our simulations with the LARS-WG software do not produce aberrant results.

We also broke down the results in Figure 4a into monthly values (Figure 4c). As can be expected, the reduction in the number of days with snowfall is strongest in mid-season (Nov – Feb). The reduction is also fairly symmetric between

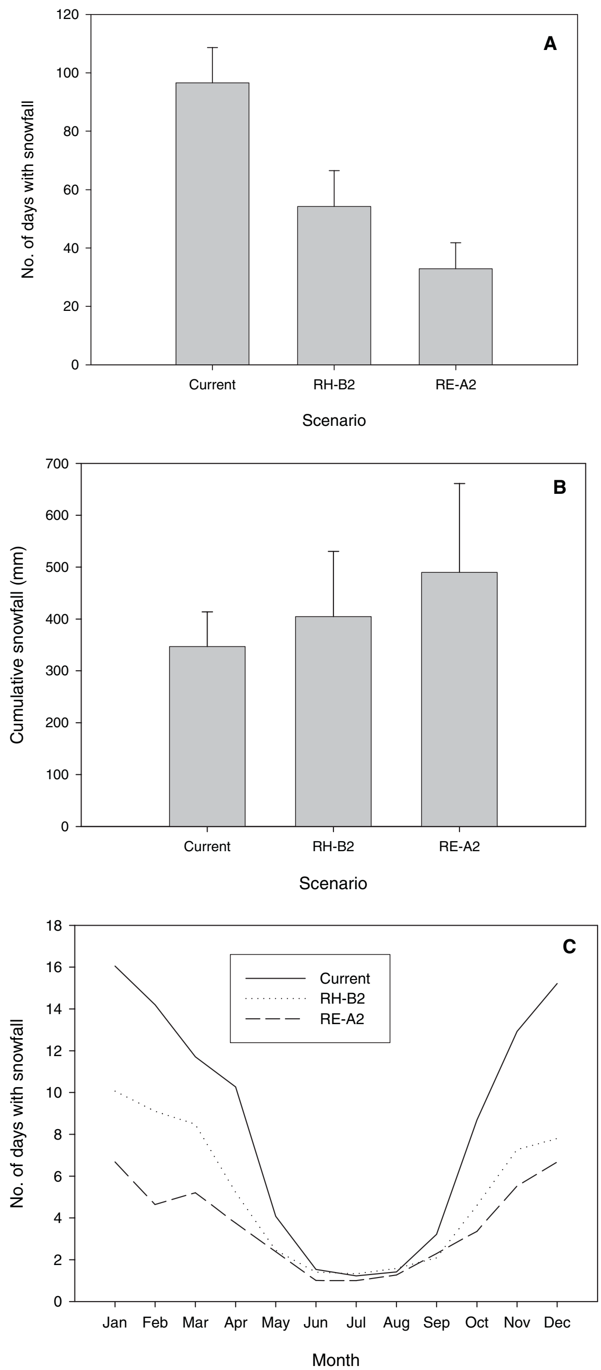

Figure 4 Climate change simulations based on data in figures 2 and 3. Mean and standard deviation based on 100 simulations. **A.** Annual number of days with snow (i.e. days with precipitation with minimum daily temperature below 0°C). **B.** Cumulative snowfall (defined as total amount of precipitation in mm during days where minimum temperature is below 0°C). **C.** Mean monthly number of days with snow

spring and autumn and will thus affect both the beginning and the end of the potential skiing season (Figure 4c). The differences between the two climate change scenarios are also strongest in mid-season with an especially strong reduction in RE-A2 in January to March. We used the data in Figure 4c to calculate a percentage of reduction in potential ski season for estimating the economic impacts.

Reduced ski season and economic impacts

The current ski season was estimated at 162 days, starting November 24 and closing May 4. This implies an early season length of 38 days, a mid-season of 90 days and late season of 34 days. Using the values in Figure 4c, the reduction in number of days with snowfall during the ski season for the period 2070–2100 is estimated at 40% under scenario RH-B2 and 59% under scenario RE-A2, relative to the current climate. This converts into 64 skiable days lost under scenario RH-B2 and 96 days days under scenario RE-A2 (Table 2). If the reduction is symmetrically distributed between the beginning and end of the ski season, 85% of the skiable days will be lost in the early season, 95% of the skiable days will be lost in the late season while the mid-season will stay unaffected under scenario RH-B2. For scenario RE-A2, both the early and late seasons will be wiped out, while the mid-season shows a 27% reduction in skiable days.

The ski season reductions above can now be used to estimate reductions in expenditures among skiers visiting the Swedish mountain region under the assumption that no redistribution of skiing or expenditure patterns occur (see discussion). Under scenario RH-B2, the 85% reduction in skiable days during the early season is equivalent to 294.6 Million SEK annually (relative to 2006 prices), while the 95% reduction during the late season is equivalent to 651.9 Million SEK annually. For scenario RE-A2, all early (346,6 Million SEK) and late (686,2 Million SEK) season expenditures will be lost, while the mid-season accounts for a 27% reduction equivalent to 722.5 Million SEK. Hence, we estimate the loss in total expenditures to be in the range of 946.5 (RH-B2) to 1755.3 Million SEK (RE-A2) annually based on future climate change (Table 2). This is more than the current ski-ticket turnover of the Swedish ski industry.

Table 2 Reduction in skiable days and total expenditures under the climate scenarios RH-B2 and RE-A2

		RH-B2		*RE-A2*	
Period	*Current ski season[1] (days)*	*Reduced ski season (days)*	*Reduced expenditures (Mill SEK[2])*	*Reduced ski season (days)*	*Reduced expenditures (Mill SEK[2])*
Nov(24) – Dec	38	−32 (−85%)	−294.6	−38 (−100%)	−346.6
Jan – Mar	90	0 (0%)	0.0	−24 (−27%)	−722.5
Apr – May(4)	34	−32 (−95%)	−651.9	−34 (−100%)	−686.2
TOTAL	162	−64 (−40%)	−946.5	−96 (−59%)	−1755.3

(1) November 24 to May 4; 2) 1 EUR ≈ 9 SEK

Discussion

Adaptation strategies to climate change

Strategies for adapting to both long term climate changes and increased risk for extreme climate events have to be developed. Bürki *et al.* (2003) presents some adaptation strategies for ski resorts (Table 3). Two of these strategies, relying on subsidies or adopting a fatalistic attitude, are probably not viable in the long run. Development of higher terrain may also be problematic. Very few alternatives exist in the relatively low altitude of the Swedish mountains and environmental protests have been raised towards such projects in the Alps (Schiermeier, 2004). It is likely that the alpine skiing industry in Sweden will have to either develop new or existing ski resorts in the north where snow conditions are likely to be more reliable, or to develop alternative tourist activities that are less dependent on snow conditions. Both of these strategies have problems. Developing ski resorts in the north means that the distance to the populated centres increases, travel costs for the tourists will increase, and less people could probably afford skiing. Fredman and Heberlein (2005) identified low income as a constraint for skiing in the Swedish mountains. Developing alternatives to skiing during winter is also problematic since many alternatives, such as snowmobiling, dog sleighing and ice fishing, are also dependent on snow cover or ice-covered lakes. The most promising strategy might be to develop all-year tourism activities. Besides counteracting negative economic effects from climate change, such a strategy will also have positive social effects on traditional winter destinations as seasonal variations in job opportunities are bridged over.

Perhaps the most common adaptation to snow-deficient winters is artificial snowmaking. Snowmaking may both be used to affect ski season lengths and to

Table 3 Adaptation strategies for ski resorts in the face of climate change (adopted from Bürki *et al.*, 2003)

Strategy	*Activity*	*Comments*
1. Maintain ski tourism	Artificial snowmaking	Expensive and requiring sub-zero temperatures
	Development of higher terrain	Generally not possible in Sweden
	Cooperation/expansion into areas with more reliable snow	Will diversify income structure
2. Subsidies	Government subsidies	Only viable for short periods if politically possible
3. Alternatives to skiing	Non-snow related activities in winter	More choices may attract tourists even if snow is lacking
	All-year tourism	Develop summer tourism
4. Fatalism	Business-as-usual	Do nothing and hope for the best
	Cancel ski tourism	Give up

decrease snow variability during the season. Climate change will affect snowmaking in four ways (Scott *et al.*, 2006): less natural snow will require more snowmaking, warmer average temperatures will reduce the duration and number of opportunities and increase the costs of making snow, and changes in precipitation may affect the water supply for snowmaking. Analyses in North America have shown that snowmaking may substantially reduce the negative impacts of climate change providing that temperature remains low enough (Scott, 2006; Scott *et al.*, 2006). However, artificial snowmaking is not without environmental and financial costs. Water withdrawals from natural water bodies may lower water levels and impact fish negatively. Energy requirements are also high and inversely related to temperature, and will thus incur higher costs the warmer the temperatures get.

Validity of expenditure estimates

To complete an economic assessment of climate change it is necessary to s utilise the best information available regarding future climate projections and ecological assessments. A difficulty with this process arises from the uncertainties involved in each component of the assessment (Ahn *et al.*, 2000). Current estimates should, therefore, be seen as 'best guesses' rather than exact numbers. The uncertainties of putting a value from climate change on the tourism sector was also addressed by the third IPCC assessment report (IPCC, 2001: 770):*'Until systematic nation-level analyses of economically important recreation industries and integrated sectoral assessments for major tourism regions have been completed, there will be insufficient confidence in the magnitude of potential economic impacts to report a range (based on disparate climate, social, technical, and economic assumptions) of possible implications for this sector'*. And, in their review of the evolution of the climate change issue in the tourism sector, Scott *et al.* (2005b: 50) conclude that *'Even today there is little research to even speculate on the potential magnitude of economic losses in the US ski industry'*.

With these possible limitations in mind, we do, however, believe that attempts to reveal economic measures are necessary in order to understand climate change in the broader economic system and to develop efficient future policies. The current study estimates economic losses in the range of 946.5 to 1755.3 Million SEK based on a static and linear relationship between projected future days with snowfall, ski-season lengths, and visitor expenditures. Like other studies in this genre, this involves a number of important restrictions to consider.

Firstly, we are holding the temporal distribution of trips and the level of expenditure fixed over the study period, which basically ignores the dynamics of supply and demand. The projected future climate change will cause a reduction in skiable days, implying a shift in the supply curve to the left, while skiers will face a shorter season and fewer substitute sites, implying a shift in the demand curve to the right. Both these changes will lead to a future increase in prices and a decrease in ski trips. According to the ski industry, resorts are not at full capacity during the mid-season (which will only be marginally affected by future climate changes). If people currently skiing in the early and late seasons change their behaviour and instead go skiing during the current mid-season our analysis will overstate the economic loss.

Secondly, by using current prices in our analysis we ignore the problem of time discounting. The economic consequences of climate change will potentially occur many years in the future and depend on the level of future real interest rates.

Thirdly, our estimates are based on the current skiing participation and population sizes, both of which will probably change in the future. If skiing participation continues to grow (as it has for the last 20 years), future economic losses will be higher than our results indicate. However, the demand for outdoor recreation participation is based on complex mechanisms dependent on, for example, the settings (environmental, social, managerial) and motivational domains (Manning, 1999). People may lose interest in those recreation activities that diminish in quality due to climate change and substitute other, more favourable, activities. If this is the case for skiing, our estimates are too high.

Finally, it should also be noted that the data used includes only Swedish visitors. Statistics from overnight stays in the mountain region show that approximately 13% of the visitors are from outside Sweden (Heberlein *et al.*, 2002). There are good reasons to assume that foreign visitors have higher expenditures in visits to the Swedish mountains than domestic visitors, partly because of an increased travel distance to get there. As we do not incorporate international visitors in our analyses, our results are probably conservative. However, one can also speculate over the impact of future climate change on international tourism patterns (e.g. Hamilton *et al.*, 2005) and find support for an increased future tourism flow to this part of the world.

Concluding Remarks

Projections of climate change (both short- and long term) show patterns of shorter snow covered periods, higher temperatures and more precipitation during winter. Some of these trends can already be seen in the data for the last few decades. These changes in climate are mostly negative for the survival and continued development of alpine winter tourism in general and for ski resorts, especially in the southern part of the mountain region. In this paper, using the southernmost major ski area in the Swedish mountains as an illustration, we have shown that future climate change may have significant negative effects on both ski season lengths and associated economic impacts.

The negative effects on snow reliability may be further strengthened by changes in the behavior of skiers. A survey among winter tourists in the Swiss Alps shows that during periods of poor snow conditions, 49% would move to a ski area with more reliable snow, 32% would ski less often, and 4% would give up skiing altogether (Bürki *et al.*, 2003). Changed behavior in relation to reliability of snow conditions will thus have strong effects on the economy of the affected ski areas. In Sweden, the number of days with snow cover has decreased substantially in the southern part of the country since the 1960s (Larsson, 2004). If this trend continues, less people in the more populated parts of the country (where most skiers live) will experience snowy conditions at home, which may further decrease the motivation and inspiration to go skiing in the north of Sweden.

Suggested climate-driven changes in Swedish downhill skiing may have several implications for future sustainable development in the mountain region. A shorter season implies diminishing employment opportunities for local residents, while disturbances on wildlife probably will decrease (Nellemann *et al.*, 2002). If all-year tourism is developed at ski resorts, the overall change may result in improved economic and social conditions. Snowmaking capacity is also likely to be increased, which implies higher costs to ski-area operators and negative environmental impacts on local communities. If skiing opportunities are moved north, it results in longer travel distances from the more populated parts of southern Sweden with resulting cost increases and environmental impacts from transportation.

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