Winter Tourism, Climate Change, and Snowmaking in the Swiss Alps: Tourists' Attitudes and Regional Economic Impacts

Authors: Pütz, Marco, Gallati, David, Kytzia, Susanne, Elsasser, Hans, Lardelli, Corina, et al.

Source: Mountain Research and Development, 31(4) : 357-362

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-11-00039.1

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

MountainResearch
Systems knowledge

Winter Tourism, Climate Change, and Snowmaking in the Swiss Alps: Tourists' Attitudes and Regional Economic Impacts

Marco Pütz[1], David Gallati[1], Susanne Kytzia[2], Hans Elsasser[3], Corina Lardelli[4], Michaela Teich[4], Fabian Waltert[1], and Christian Rixen[4]*

** Corresponding author: marco.puetz@wsl.ch*

[1] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürcherstrasse 111, 8903 Birmensdorf, Switzerland

[2] University of Applied Sciences HSR, Oberseestrasse 2, 8640 Rapperswil, Switzerland

[3] Department of Geography, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland

[4] WSL Institute for Snow and Avalanche Research SLF, Flüelastrasse 11, 7260 Davos, Switzerland

Technical snowmaking has become an important measure in winter tourism destinations to deal with decreasing snow reliability, seasonal weather variability, and growing customer demand. This study analyzes tourists' attitudes toward technical snowmaking, their preferences for snow reliability, and other factors that influence destination choice. We interviewed tourists at 3 Swiss winter tourism destinations: Davos, Scuol, and Braunwald. In addition, we analyzed the impact of technical snowmaking on the regional economy in Davos with a scenario analysis based on a simplified model of the regional economy related to tourist behavior. The 3 destinations showed large regional and seasonal differences in tourists' attitudes toward technical snowmaking and the importance of factors that influence destination choice. Generally, technical snowmaking is being increasingly accepted among tourists. It can be considered as insurance for snow reliability. In major tourist destinations that focus on skiing for winter tourism, the potential damage to mountain railways and hotels from lack of snow can be great enough to justify the costs of technical snowmaking. But snow reliability is not the most crucial factor that affects the attractiveness of destinations in general. Our results show that the European Alpine landscape and a wide choice of activities in the winter as well as the summer season are the most important factors that influence destination choice. In some cases, therefore, it may be economically reasonable to refrain from technical snowmaking and redirect investment to tourist attractions independent of snow conditions.

Keywords: *Attitudes; artificial snow; snowmaking; ski piste; climate change; winter tourism; regional economy; Switzerland.*

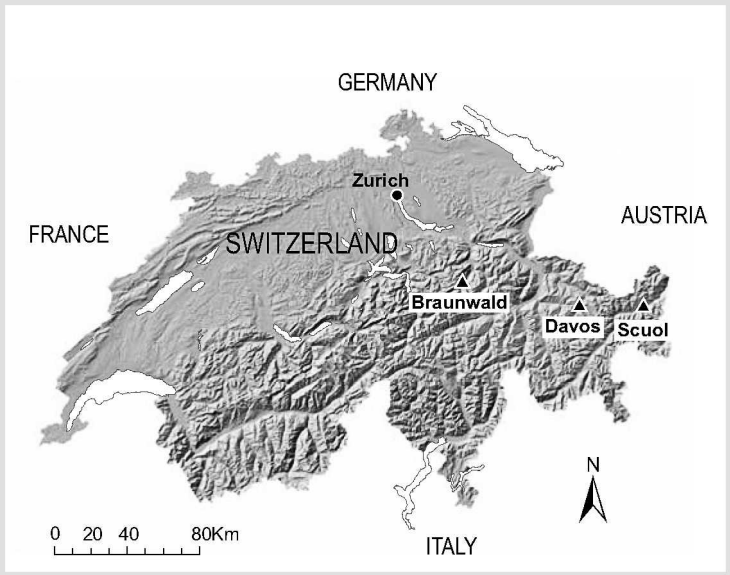
Peer-reviewed: *July 2011* ***Accepted:*** *August 2011*

Introduction

Climate change is expected to have considerable impacts on European Alpine tourism (Abegg 1996; Elsasser and Messerli 2001; Pröbstl 2006; OcCC 2007). The increasing number and intensity of natural hazards is endangering the accessibility and the infrastructure of tourism destinations. Melting glaciers are affecting the attractiveness of the Alpine landscape (OcCC 2007). Increasing winter temperatures will result in a shorter skiing season (Scott et al 2003) and a shift of the natural line of snow reliability to higher altitudes (Abegg et al 2007; Steiger 2010). Lack of snow (as in the winter 2010–2011 in most parts of the Swiss Alps), decreasing snow cover and snow depth (Laternser and Schneebeli 2003), and decreasing snow reliability could lead to smaller number of visitors and reduced revenues, and thus have severe economic impacts on winter tourism destinations in the Alpine space (Scott et al 2007; Müller and Weber 2008; Unbehaun et al 2008). Meier (1998) estimates the annual economic losses in Swiss winter tourism due to climate change at US$ 1.9 to 2.45 billion (with reference to an average temperature rise of 2°C, 2030–2050).

Natural snow reliability is defined by the "100-days-rule" proposed by Witmer (1984), enhanced by Abegg (1996) and Bürki (2000), and further adopted in a recent Organisation for Economic Co-operation and Development study (Abegg et al 2007). The "100-day-rule" states that natural snow reliability in a region is given if there is sufficient snow cover of at least 30 cm for skiing on at least 100 days between 16 December and 15 April in 7 of 10 years (Abegg 1996; Bürki 2000). A future temperature rise of 4°C by 2010 will raise the line of snow reliability from the recent altitude of 1200 m to approximately 1800 m in the Central Alps and to 2100 m in the Southern Alps (Abegg et al 2007: 34).

FIGURE 1 Location of the 3 study areas in the Swiss Prealps and Alps, and proximity to the Zurich metropolitan region. (Map by Marco Pütz)



One of the key strategies for dealing with decreasing snow reliability and adapting to climate change impacts in general is the production of artificial snow. The number of snowmaking plants and the area of ski piste covered with artificial snow has increased significantly in the Alps in recent years. In Switzerland, the ski piste area covered with artificial snow was tripled in just 10 years, from 2000 to 2010 (from <10% up to 33% of the total ski piste area); Austrian winter tourism destinations produce artificial snow for about 60% of their ski piste area, and, in the Italian Alps it goes up to 100% (Rixen et al 2011). However, there are numerous concerns about artificial snow and snowmaking: high levels of water and energy consumption for snowmaking (CIPRA 2004), the negative impacts of snowmaking on vegetation and soil (Keller et al 2004; Rixen et al 2008; Roux-Fouillet et al 2011), negative economic impacts on winter tourism when less visitors go to skiing destinations (Bürki and Elsasser 2000), and controversial snowmaking potential in a warmer climate with higher temperatures (Steiger and Mayer 2008).

The present article first investigates the attitudes and preferences of tourists and stakeholders concerning artificial snow and, second, the impacts of snowmaking on the regional economy in winter tourism destinations. Both topics deal with economic aspects of artificial snow but from different complementary perspectives: (1) the actor perspective, which consists of artificial snow users and stakeholders, and (2) the impact perspective, which consists of the regional economic impact of snowmaking. Accordingly, 2 research questions are addressed: (1) what are tourist and stakeholder attitudes and preferences toward artificial snow in the Swiss Alps, and (2) to what extent does snowmaking contribute to regional economic development in the Swiss Alps? The answers to these questions help to assess the economic impacts of artificial snow and snowmaking. They also provide support for tourism planning and the development of climate change adaptation strategies in winter tourism destinations.

Methodology

Case studies

Three winter tourism destinations in the Swiss Alps were selected as case studies: Davos (9° 50′ E, 46° 48′ N), Scuol (10° 18′ E, 46° 48′ N) and Braunwald (8° 59′ E, 46° 56′ N). These destinations are different in terms of size, altitude, climatic conditions, and tourism structures (for details see Teich et al 2007). Davos (12,500 inhabitants) features 5 ski resorts, which range from 1560 to 2844 m, provides 20% to 45% of ski slopes with snowmaking facilities, and is renowned for winter sports as well as health and congress tourism. Scuol (2400 inhabitants) has 1 ski resort, which ranges between 1250 and 2785 m, provides 30% of ski slopes with snowmaking, and is well known for its dry climate (750 mm annual precipitation, 6°C mean annual temperature), and a spa. Braunwald is the smallest case study destination, with 350 inhabitants, and 1 ski resort, which ranges between 1250 and 1904 m, and provides 3% of ski slopes with snowmaking. Braunwald is well established as a car-free and family-friendly destination, and is located close to the Zurich metropolitan region (Figure 1).

Tourists' attitudes toward technical snowmaking

Standardized interviews with tourists were carried out to first analyze the criteria for choosing a holiday destination and second to assess whether tourists perceive snowmaking as an appropriate adaptation

strategy to deal with decreasing snow reliability. The interviews consisted of 4 parts, including open and closed questions (see Teich et al 2007 for a detailed questionnaire): (1) origin, time, and place of stay; (2) priority of attractions in the destination; (3) perception of artificial snow and attitudes toward snowmaking; and (4) demographic and socioeconomic profile of interviewee (age, job, etc). A random selection of tourists was interviewed face-to-face in the 3 tourist destinations in summer and winter 2006–2007. Survey points were located at tourism hotspots to sample a representative cross section of all tourists during 2 days per destination in summer, winter preseason, and the main season. A total number of 791 tourists were interviewed, evenly distributed across sites and dates.

In oral expert interviews with local stakeholders from mountain railway companies and public administration, current and future adaptation strategies for climate change and decreasing snow reliability were investigated. The interviews focused on 6 topics: (1) climate change and consequences for the winter sport destination, (2) expert opinion on snowmaking, (3) snowmaking facilities and resource consumption in the respective ski area, (4) financing of snowmaking, (5) snow-independent strategies for adapting to rising temperatures, and (6) collaborations among stakeholders. The topics functioned as guidelines, and the experts could expand on specific topics. Six interviews (30–90 minutes each) were carried out by using the protocol in Meuser and Nagel (2005).

Regional economy

To investigate the effects of snowmaking on the regional economy, we analyzed its added value for the community of Davos. The analysis was based on a scenario analysis for different cause–effect relations between snowmaking and the regional economy. We analyzed these cause–effect relations in 2 steps. We first described how snowmaking affects tourist behavior. Because no empirical evidence for this cause–effect relation was available, we developed different scenarios, which depict a number of plausible cause–effect relations for the community of Davos. The definition of these scenarios was based on expert knowledge derived from observations, interviews, and analysis of data from the mountain railways. The plausibility of the cause–effect relations is based on the literature about climate change and winter tourism (Pröbstl 2006; Steiger and Mayer 2008; Unbehaun et al 2008) and is also supported by findings from the stakeholder interviews. In the first scenario, we assumed that artificial snow is a precondition for skiing down to the valley bottom at low season (before Christmas and after March). By using this assumption, we supposed that the number of skiers on weekends rises to 30% during this period as a result of snowmaking. In the second scenario, we assumed that artificial snow is perceived as a signal of reliable snow conditions, in general, for tourists who book long term in advance. We assumed that this signal results in additional overnight stays of 10% each winter season. In the third scenario, we assumed that artificial snow can reduce risk during winter seasons when the possibilities for skiing are severely hampered by bad snow conditions. We assumed that such an event occurs every 25 years on average and can lead to a decrease of overnight stays by 30% in the year itself and in total by 30% in the following 5-year period.

We then modeled the relation between tourist behavior and factored income in the community of Davos with a combination between a regional input–output (IO) model and a model for tourist behavior. The regional IO model shows the interrelationships between industries within an economy with respect to production and the use of products and services, including imports, exports, and capital formation. The database is an IO table (IOT) for the community of Davos from 2002 (Wegmann and Kytzia 2005), which provided data on the monetary value of all products and services as well as their origin and destination within the regional economy. It was constructed by using a so-called hybrid approach, which is based on surveys and adaptations of other IOTs. Full surveys, interviews, and literature studies were carried out for mountain railways, hotels and restaurants, clinics and hospitals, the municipality, agriculture, wholesale and retail trade with food, construction, and electricity supply. These industries covered approximately 70% of all employees and 60% of the total value of production. Basic data for the remaining industries was taken from the regional IOT for Styria, Austria (Fritz et al 2003). This base matrix was chosen because the economic structure of Styria was closer to an alpine tourist region such as Davos than the structure of any other economy with an IOT available at the time of the study. Several sectors found in Styria but not in Davos were completely shifted to focus on the imports of Davos. The level of sector aggregation was found suitable, and only the transport sector was further disaggregated by means of survey data. Yet, the Styria matrix does not fully meet the desirable qualities of a basic matrix because it was derived from a national table that originated from 1995. Therefore, the methodological focus of the study was shifted from an optimal choice of the basic matrix and its regionalization to an extended sector survey, as described above.

The model for tourist behavior was based on a survey of consumer behavior in the Canton of Valais (Rütter et al 2001). It defines 12 different categories of tourists and estimates the average amount spent per day for different services, for example, accommodation, food, skiing. In our model, we assumed that these values can be used as best estimates for tourism in Davos and that they remain constant over time. We combined both models by linking the vector of final demand in the IO model with the model for tourist behavior. The combined model showed

http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00039.1

how variation in the number and mix of tourists affected the factor income for Davos.

Results and discussion

Tourists' attitudes and preferences

More summer tourists opposed than supported artificial snow (40% versus 33%). Although this finding holds for all 3 destinations, the difference in the frequency of opponents and supporters was not statistically significant. The most common arguments against snowmaking were ecological reasons and the use of resources. A significant majority of winter tourists, however, supported snowmaking in Davos (56% versus 33%, significance at $P < 0.01$) and Scuol (54% versus 34%, $P < 0.01$) but not in Braunwald (35% versus 54%, $P < 0.05$). Overall, winter tourists tend to support artificial snow (49% versus 40%, $P < 0.05$). The most common arguments for snowmaking were the quality of the ski pistes, the necessity for climatic reasons, and economic reasons. Interestingly, 57% of skiers were opposed to artificial snow in 1990 (Studer and Christoffel 1990).

When asked for the main reason why a destination was chosen, tourists in Braunwald named the tranquility, the beauty of the landscape, and the fact that Braunwald was car free and family friendly. In Scuol, the landscape, the nice weather, and winter sport opportunities were mentioned. In Davos, skiing, other outdoor activities, and infrastructure were the main reasons.

The open question about reasons to choose a destination was answered by good snow conditions in only 3% of the cases. However, when asked in a closed question how important reliable snow conditions were in the choice of destination, 88% of the tourists considered this to be very important. This result indicates that most tourists probably took reliable snow conditions for granted. At least one quarter of the tourists (up to 40% in winter season) could be identified as potential dropouts, who would avoid the chosen destination in the event of poor snow conditions.

The highly mixed responses of tourists demonstrated clearly that a diversification in tourism is an advisable strategy to meet increasing economic competition and less reliable snow conditions (Bürki and Elsasser 2000; Pröbstl et al 2008). Many tourists appreciate that, for instance, Braunwald offers family-friendly tourism and a beautiful landscape. Here, snow reliability is not the most important factor in tourism. Most destinations, therefore, are probably best advised to preserve and enhance their summer landscape beauty and to rely not only on intensifying winter tourism (Müller and Weber 2008). Nevertheless, snowmaking might be an option in destinations such as Davos for instance, with higher altitudes, higher snow reliability, and a stronger focus on winter sports. Congruently, the local stakeholders in our study regions reflected our findings on tourist perception. On the one hand, the stakeholders clearly stated that the mountain railway companies were the "motor" of a destination that enabled winter sports and were the basis of the large economic sector of winter tourism. On the other hand, stakeholders at all destinations realized that summer tourism is and will become more important and that diversification in tourism will probably be crucial to make a destination stand out from other destinations and be able to compete.

Regional economy

The analysis of the regional added value demonstrated the central role of the tourism sector for the economy of Davos: 40% of the aggregate demand was generated by tourism. Winter tourism contributed 26% to aggregate income, and mountain railways generated 5% of the total aggregate income. Our calculations showed that losses of up to 10% of the regional factor income in the community of Davos (approximately US$ 67 million) could be prevented by snowmaking in winters with poor snow conditions. The mountain railways and the hotel and restaurant industry would profit most from preventing losses. The 3 scenarios contributed equally to this overall effect by approximately 3% for each scenario (Table 1).

These results are significantly influenced by uncertainties in the estimation of the parameter values in the IO model, the model of tourist behavior, and scenario definition. It is very difficult to assess these uncertainties in a meaningful and systematic way, because different methods were used for parameter estimation, ranging from surveys (IO model) to "informed guesses" (scenario definitions). Uncertainties in scenario definition are most significant for the results of this analysis and are hardest to qualify. Uncertainties in the combined model for the regional economy are smaller because it was possible to validate model results with survey data. Uncertainties in assumptions about tourist behavior, however, have a greater impact on the results of the study than uncertainties in IO coefficients.

These numbers represent an estimate of the potential economic damage in a tourist destination focused on skiing in winter tourism. The estimate of the potential economic damage varies, depending on the size of the destination and the importance of snow-related winter sports. Therefore, the potential economic damage is greater in Davos than in Braunwald. Yet the risk related to this potential damage also depends on the probability of insufficient snow cover, which is much higher in resorts with low altitude (such as Braunwald). Thus, destinations at low altitudes may face a higher risk to their tourist industries due to insufficient snow conditions. Yet the results of our study show that technical snowmaking is not the only strategy for meeting such risks.

The outputs from the model scenarios can only estimate the economic role of snowmaking for the total

TABLE 1 Results of scenario analysis for changes in regional factor income (as a percentage of the values of 2002).

	Scenario 1: Skiing to valley bottom	Scenario 2: Signal for reliable snow condition	Scenario 3: Risk reduction for winters with no snow
	Change in regional factor income (% of the values of 2002)		
Agriculture and forestry	0.7	0.8	0.9
Manufacturing and construction	1.3	1.5	1.7
Wholesale trade	1.7	2.0	2.2
Retail trade	2.8	3.2	3.5
Hotels and restaurants	9.7	11.1	12.3
Land transport	5.2	6.0	6.6
Mountain railways	13.4	15.5	17.0
Other services	5.3	6.1	6.7
Education	2.0	2.3	2.5
Health and social works	0.6	0.7	0.7
Total	2.8	3.3	3.6

aggregate income because artificial snow represents only one of several important factors in winter tourism. However, artificial snow is the one factor that can currently guarantee reliable snow conditions for winter sports and, therefore, can prevent potential losses in aggregate income in winters with poor snow conditions. The calculations of potential losses in income are only valid based on today's economic numbers, and it is uncertain whether winter tourists would still visit destinations if they could only or mostly ski on artificial snow (Pröbstl 2006; Müller and Weber 2008). At least in the short term, however, it seems that Davos could be a winner in years with generally poor snow conditions: during the poor winter 2006–2007, the income of Swiss Mountain railways decreased by 5%, but Davos actually had no reduction in tourist numbers (see also Bürki and Elsasser 2000; Pröbstl et al 2008).

Conclusions and implications

Our results show the importance of a profound site-specific understanding of visitor attitudes and preferences in developing a competitive tourism strategy. Tourists and stakeholders perceived the snow reliability of a tourist destination as very important but also acknowledged qualities of destinations that are not associated with snow conditions. This clearly indicates a need for more research on the demand side. Further research must focus on the motives for choosing a destination and particularly on the role of environmental or climate concerns in the destination choice. There also is a need for more empirical studies to compare tourist's attitudes and preferences for artificial snow among different resorts and to monitor the change of tourist's attitudes and preferences. Snowmaking, as the current response of winter tourism resorts, has to be evaluated in terms of costs and benefits, long-term impacts, and sustainability (Pickering and Buckley 2010).

Attitudes toward artificial snow and snowmaking are coherent, with the visitor structure being an important driving factor. The seasonal differences in acceptance can be ascribed to the various portions of interviewees who engaged in skiing; 68% of interviewed persons in the summer were used to skiing during winter, and 88% of interviewees skied in winter. There was a significant correlation between a positive attitude toward artificial snow and engagement in skiing. Further, skiing was a crucial factor in destination choice for visitors in Davos and Scuol during winter. The requirements for skiing infrastructure were accordingly high, showing a positive impact on the acceptance on artificial snow. However, in Braunwald, where the original offerings were more important than developed tourism infrastructure, acceptance was low.

Compared with older studies (Studer and Christoffel 1990; Bürki 2000), overall acceptance increased in the 1990s. Although 36% of interviewed skiers in the study by Studer and Christoffel (1990) supported the adoption of snowmaking, on average 51% did so in the present study. In the study by Bürki (2000), 46% of skiers considered snowmaking important. The increasing acceptance implicates familiarization with widespread snowmaking and the related advantages in tolerating snowmaking as a certain necessity for the economic survival of peripheral regions in the context of climate change and international competition. Interviewees seldom stated

http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00039.1

vehement opposition to snowmaking. However, many of them (up to 34% in Davos) were indifferent, and either did not offer reflections or acted ambivalent. Many in this group had a rather negative attitude about snowmaking but did not want to abstain from attractive slope conditions. Further, it must be stated that many skiers arguing against the application of artificial snow skied, nevertheless, did so frequently on artificial snow without appreciating it. Finally, snowmaking does not seem to be highly appreciated by skiers but rather accepted as a basic requirement at winter tourism destinations.

The study demonstrated that the 3 destinations studied, Davos, Scuol, and Braunwald, are not only different in climate conditions and in altitude but also in terms of local tourism strategies, visitor structure, tourist activities, and tourist preferences. Given the increasing economic competition and the changing climate, it will be crucial to use specific regional strengths to provide high-quality summer and winter tourism activities. Snowmaking at the high-altitude destinations Davos and Scuol represents a valuable strategy to enhance winter tourism. Each new snowmaking plant needs to be checked for its economic cost efficiency and potential ecological impacts (Williams and Todd 1997; Rixen et al 2011). To optimize this process, all relevant stakeholder groups, that is, mountain railway companies, communities, tourism organizations, and nature conservation agencies need to collaborate as early as possible in the planning process.

ACKNOWLEDGMENTS

This study was funded by the MAVA foundation. We are grateful to all stakeholders from the investigated municipalities of Davos, Scuol, and Braunwald for their support. We also wish to thank all interviewees.

REFERENCES

Abegg B. 1996. *Klimaänderung und Tourismus: Klimafolgenforschung am Beispiel des Wintertourismus in den Schweizer Alpen*. Zurich, Switzerland: vdf Hochschulverlag.

Abegg B, Agrawala S, Crick F, de Montfalcon A. 2007. Climate change impacts and adaptation in winter tourism. *In:* OECD (Organisation for Economic Co-operation and Development). *Climate Change in the European Alps*. Paris, France: OECD, pp 25–60.

Bürki R. 2000. *Klimaänderung und Anpassungsprozesse im Wintertourismus*. Publikationen der Ostschweizerischen Geographischen Gesellschaft, Neue Folge, 6. St. Gallen, Switzerland: Ostschweizerische Geographische Gesellschaft.

Bürki R, Elsasser H. 2000. Touristische Nachfragetrends und Klimawandel in den Alpen. *Montagna* 1/2:13–16.

CIPRA [International Commission for Protection of the Alps]. 2004. Künstliche Beschneiung im Alpenraum. Ein Hintergrundbericht. Schaan, Lichtenstein: CIPRA.

Elsasser H, Messerli P. 2001. The vulnerability of the snow industry in the Swiss Alps. *Mountain Research and Development* 21:335–339.

Fritz O, Kurzmann R, Streicher G, Zakarias G. 2003. Constructing regional input–output tables in Austria. *Austrian Economic Quarterly* 1:1–39.

Keller T, Pielmeier C, Rixen C, Gadient F, Gustafsson D, Staehli M. 2004. Impact of artificial snow and ski-slope grooming on snowpack properties and soil thermal regime in a sub-alpine ski area. *Annals of Glaciology* 38:314–318.

Laternser M, Schneebeli M. 2003. Long-term snow climate trends of the Swiss Alps (1931–99). *International Journal of Climatology* 23:733–750.

Meier R. 1998. *Sozioökonomische Aspekte von Klimaänderung und Naturkatastrophen in der Schweiz*. Zurich, Switzerland: vdf Hochschulverlag.

Meuser M, Nagel U. 2005. ExpertInneninterviews—vielfach erprobt, wenig bedacht: Ein Beitrag zur qualitativen Methodendiskussion. *In:* Bogner A, Littig B, Menz W, editors. *Das Experteninterview: Theorie, Methode, Anwendung*. Wiesbaden, Germany: Verlag für Sozialwissenschaften, pp 71–93.

Müller H, Weber F. 2008. Climate change and tourism: Scenario analysis for the Bernese Oberland in 2030. *Tourism Review* 63:57–71.

OcCC [Organe consultatif sur les changements climatique, Advisory Body on Climate Change]. 2007. Klimaänderung und die Schweiz 2050. Bern, Switzerland: OcCC.

Pickering CM, Buckley R. 2010. Climate response by the ski industry: The shortcomings of snowmaking for Australian resorts. *AMBIO* 39:430–438.

Pröbstl U. 2006. *Kunstschnee und Umwelt. Entwicklung und Auswirkungen der technischen Beschneiung*. Bern, Switzerland: Haupt Verlag.

Pröbstl U, Unbehaun W, Haider W. 2008. Trends in winter sport tourism: Challenges for the future. *Tourism Review* 63:36–47.

Rixen C, Freppaz M, Stoeckli V, Huovinen C, Huovinen K, Wipf S. 2008. Altered snow density and chemistry change soil nitrogen mineralization and plant growth. *Arctic Antarctic and Alpine Research* 40:568–575.

Rixen C, Teich M, Lardelli C, Gallati D, Pohl M, Pütz M, Bebi P. 2011. Winter tourism and climate change in the Alps: An assessment of resource consumption, snow reliability and future snowmaking potential. *Mountain Research and Development* 31(3):229–236.

Roux-Fouillet P, Wipf S, Rixen C. 2011. Long-term impacts of ski piste management on alpine vegetation and soils. *Journal of Applied Ecology* 48(4): 906–915.

Rütter H, Berwert A, Rütter-Fischerbacher U, Landolt M. 2001. *Der Tourismus im Wallis*. Wertschöpfungsstudie. Visp, Rüschlikon, Siders, Switzerland: Rütter + Partner concert research, Forschungszentrum der Schweizerischen Tourismusfachschule (STF). http://www.vs.ch/Press/DS_3/CP-2001-06-11-32/de/CPD110601_document.pdf; accessed on 27 September 2011.

Scott D, McBoyle G, Mills B. 2003. Climate change and the skiing industry in southern Ontario (Canada): Exploring the importance of snow-making as a technical adaptation. *Climate Research* 23:171–181.

Scott D, McBoyle G, Minogue A. 2007. Climate change and Quebec's ski industry. *Global Environmental Change* 17(2):181–190.

Steiger R. 2010. The impact of climate change on ski season length and snow-making requirements in Tyrol, Austria. *Climate Research* 43:251–262.

Steiger R, Mayer M. 2008. Snow-making and climate change: Future options for snow production in Tyrolean ski resorts. *Mountain Research and Development* 28:292–298.

Studer N, Christoffel J. 1990. *Beschneiungsanlagen und künstlich erzeugter Schnee im Urteil von Skifahrern und Kur- und Verkehrsdirektoren* [Lizentiat thesis]. Bern, Switzerland: University of Bern.

Teich M, Lardelli C, Bebi P, Gallati D, Kytzia S, Pohl M, Pütz M, Rixen C. 2007. *Klimawandel und Wintertourismus: Ökonomische und ökologische Auswirkungen von technischer Beschneiung*. Birmensdorf, Switzerland: Eidgenössisches Forschungsanstalt für Wald, Schnee und Landschaft (WSL).

Unbehaun W, Pröbstl U, Haider W. 2008. Trends in winter sport tourism: Challenges for the future. *Tourism Review* 63:36–47.

Wegmann M, Kytzia S. 2005. *Input–Output–Table for Davos, 2002. Report*. Zurich, Switzerland: Chair for Regional Resource Management.

Williams PW, Todd SE. 1997. Towards an environmental management system for ski areas. *Mountain Research and Development* 17:75–90.

Witmer U. 1984. *Eine Methode zur flächendeckenden Kartierung von Schneehöhen unter Berücksichtigung von reliefbedingten Einflüssen*. Geographica Bernensia G21. Bern, Switzerland: Geographica Bernensia.

http://dx.doi.org/10.1659/MRD-JOURNAL-D-11-00039.1