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Impact of Weather on Downhill Ski Lift Ticket Sales

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Skiing heavily relies on specific weather and environmental conditions to make participation both feasible and enjoyable. The lack of published research on the relationships among ski activity, weather, and climate is, therefore, surprising, especially in light of mounting evidence regarding climate change. The analyses of the influence of daily weather variations on daily ski lift ticket sales at two Michigan ski resorts presented here appear to be the first of their kind. Results suggest that weather variables such as minimum and maximum temperature, snow depth, and wind chill do indeed have a statistically significant impact on downhill ski lift ticket sales. The regression models developed could be used by outdoor recreation and tourism providers for both short-term decision making and longer-term planning and management activities, in particular those involving consideration of climate change and potential adaptation strategies.

Keywords: *weather variability; climate change; skiing; Michigan*

Outdoor recreation and tourism (ORT), along with auto manufacturing and agriculture, is one of the three largest industries in Michigan and is extremely important to the state's economy. Among the many activities associated with ORT, skiing is one of the most popular winter season attractions for Michigan residents and out-of-state tourists alike. According to a report by the National Ski Area Association (NSAA), Michigan had the second highest number of ski areas in operation in the United States in the 2004-2005 ski season, trailing only the state of New York (NSAA 2005). As a result, the ski industry contributes greatly to the creation of jobs and income within the state. It has been estimated that during the 2000-2001 ski season, a total of 2.2 million skiers visited downhill ski areas in Michigan, generating $146 million of spending, yielding $136 million in direct sales, $54 million in direct personal income, and $86 million in value added, and supporting 3,900 jobs within the state (Stynes and Sun 2001).

Skiing, even more so than most other ORT activities, relies heavily on specific weather and environmental circumstances to make participation both feasible and enjoyable. Crowe, McKay, and Baker (1973) defined activity seasons and activity days for several outdoor recreation pursuits in Canada. With respect to skiing, their definition of a skiable day included the requirement of at least 6 hours between 8:00 a.m. and 6:00 p.m. with 2.5 cm of snow on the ground, an air temperature between –20ºC and +5ºC, winds less than 6.5 ms^{-1}, visibility better than 0.8 km, and no liquid precipitation. More recently, Scott, McBoyle, and Mills (2003) updated these climatic thresholds to more realistic levels based on examination of observed ski operations data and discussion with ski industry members. Thus, they assumed that a ski area would be closed if any of the following were to occur: snow depth less than 30 cm, maximum temperature greater than 10°C for two consecutive days accompanied by liquid precipitation, or 2 days of liquid precipitation totaling more than 20 mm.

Considering the dependency of ORT activities such as skiing on climatic and related environmental conditions, the relative lack of published research on the relationships among participation in ORT activities, weather, and climate is surprising. When combined with mounting evidence regarding climate change, this lack of knowledge should be of special concern to ORT researchers and the ORT industry. The majority of scientists today acknowledge that the world's climate is warming. According to the Intergovernmental Panel on Climate Change (IPCC 2007), the global average surface temperature has increased 0.74°C since 1861, and the 1990s were the warmest decade since records began.

Moreover, 11 of the 12 warmest years on record since 1850 have occurred in the past 12 years. While estimates do vary depending on the modeling procedures employed, climate change scenarios indicate that the global average surface temperature will increase further, by between 1.1°C and 6.4°C, by 2100, with the greatest warming occurring over land and at high northern latitudes (IPCC 2007). Nevertheless, discussion of the implications of climate change projections for the ORT industry remains largely absent from the ORT literature, despite continued calls for greater attention to this issue (e.g., Butler 2001; Hall and Higham 2005). For example, a search of the online archives revealed just two articles on the topic in *Journal of Travel Research* (*JTR*; Belle and Bramwell 2005; Amelung, Nicholls, and Viner 2007).

The few studies that have to date addressed the potential impacts of climate change on the ski sector have tended to be relatively narrowly focused in two distinct perspectives. First, they have concentrated geographically on the North American, primarily Canadian (e.g., Harrison et al. 1986; Lamothe and Périard Consultants 1998; Lipiski and McBoyle 1991; Scott, McBoyle, and Mills 2003; Scott et al. 2006), and European (e.g., Breiling and Charamza 1999; Elsasser and Messerli 2001; Elsasser and Bürki 2002; Harrison, Winterbottom, and Sheppard 1999; Koenig and Abegg 1997) ski markets. And second, they have adopted an almost exclusively supply-side approach, addressing impacts from the perspective of likely changes to snow cover, snow reliability, the length of the ski season, and/or to the number of skiable days rather than actual changes in demand for or participation in winter sports activities based on observed weather conditions and skier behavior.

The majority of North American analyses of the likely impacts of climate change on skiing have emanated from the Faculty of Environmental Studies at the University of Waterloo, Canada. The studies conducted by the researchers in this unit have consistently demonstrated the negative implications of projected climate change for skiing in Canada and the United States, though more recent analyses incorporating the counteractive effect of current and improved snowmaking technologies have suggested that the deleterious impacts on length of ski season and number of skiable days might not be as dire as earlier anticipated (e.g., Harrison et al. 1986; Lipiski and McBoyle 1991; Scott, McBoyle, and Mills 2003; Scott et al. 2006). Nevertheless, even under the assumption of improved snowmaking technology (under which the minimum temperature for efficient snowmaking is increased from –5°C to –2°C), the length of the ski season at the Horseshoe Ski Resort in southern Ontario, Canada, for example, is still projected to decline by between 1% and 21% by the 2050s and by between 4% and 39% by the 2080s, the variation in decline being accounted for by the climate change scenario employed in the analyses (Scott, McBoyle, and Mills 2003).

Examination of the likely impacts of climate change on skiing in Europe has concentrated, predictably, on the Alps. Koenig and Abegg (1997), for example, found that, while 85% of all Swiss ski areas are currently snow reliable (defined as experiencing at least 100 days per season with sufficient (i.e., 30 cm) snow cover), only 63% will remain snow reliable given a temperature rise of 2°C because of a rise in the line of snow reliability from 1,200 m above sea level (masl) to 1,500 masl. This proportion would fall further, to 44%, assuming a rise in the line of snow reliability to 1,800 masl (Elsasser and Bürki 2002). In an Austrian context, Breiling and Charamza (1999) also demonstrate the particular vulnerability of lower-altitude ski resorts to warming conditions.

In a non–North American or European context, the implications of projected climate change for skiing appear to have been considered on an empirical basis only in Australia. Galloway (1988) investigated the potential impacts of two climate change models on three ski resorts in the southeastern portion of that nation and projected declines in snow season length from 130 to 60 days, 135 to 60 days, and 81 to 15 days, respectively, assuming an increase in average winter temperatures of 2°C and a decrease in precipitation of 20%. Building on these negative projections, König (1998) conducted surveys of skiers and snowboarders at three ski resorts in New South Wales, finding that of the 926 usable responses, 44% of respondents would either give up skiing or ski elsewhere (outside Australia) if they knew in advance that the following five winters would have very little natural snow. This study appears to remain the only investigation of winter snow enthusiasts' likely behavioral reactions to climate change in the published literature. The potential for changes in winter snow conditions and anecdotal consideration of the impacts of these changes on ski activity have also been recognized for the Moroccan High Atlas region (Parish and Funnell 1999).

The analyses described above have, with one exception, consistently failed to incorporate consideration of changing demand for, and participation in, skiing as a result of changing climatic conditions. Rather, they have solely focused on supply factors such as snow reliability, season length, and numbers of skiable days. Nor have they considered alterations in other key factors influencing ORT participation, such as the prevailing economic situation and the availability of leisure time. According to Scott, McBoyle, and Mills (2003, p. 180), "The current understanding of how recreational users and tourists respond to climate variability is very limited," and "additional research on the impacts of climate change for recreation and tourism demand is required." Finally, the majority of analyses have been conducted for large geographic areas, yet, as noted by Harrison, Winterbottom, and Sheppard (1999, p. 203), such "coarse spatial resolution of climate variation . . . cannot be readily applied with any confidence to the tourist industry, where activity patterns are often strongly localized in nature."

Meaningful analysis of the likely impacts of projected climate change on ORT activity and sales from a demand perspective first requires understanding current relationships between participation in or sales of the activity and weather conditions. However, very few studies focusing on the relationship between ski participation and weather conditions appear to exist, and the two that were identified (Loomis and Crespi 1999; Mendelsohn and Markowski 1999) exhibit considerable methodological deficiencies. Loomis and Crespi (1999) attempted to model the relationship between downhill and cross-country skiing (as measured by national data on skier days) and five independent variables, namely, lift ticket costs, gasoline prices, income, temperature, and precipitation, for the United States. However, their model was "unsatisfactory. The price and income coefficients were poorly behaved, and temperature and precipitation were insignificant" (Loomis and Crespi 1999, p. 301). As an alternative, a recreation site choice model developed for a set of downhill ski areas in Colorado was applied to a national sample of major ski areas. While this method did enable very approximate estimation of the potential impacts of projected climate change on skier days and economic value, clear relationships between weather conditions and ski participation were not quantified by the authors.

Mendelsohn and Markowski (1999) examined the impact of nine different climate change scenarios on skiing activity in the United States based on annual, state-level data. Linear and loglinear regression of climate, income, and population data on activity levels failed to reveal significant relationships between ski activity and winter temperatures or winter precipitation. Nevertheless, both linear and loglinear demand models suggested large potential declines in ski activity with projected increases in temperature and precipitation.

In both of the above cases, the authors presented analyses of the impacts of projected climate change on skiing activity based on models of current participation using annual, state, or national data. However, skiing conditions vary at finer temporal and spatial scales than were employed in these studies, as noted above. The only study located by the authors (with kind thanks to the *JTR* editor for its identification) that does make mention of the collection of ski participation data at the daily level then went on to analyze these data on an annual basis, for a total of 26 ski resorts throughout northern New England (i.e., at a regional level; Echelberger and Shafer 1970). More extensive analysis of the impacts of micro-level variations appears to have been prevented to date by the lack of fine-scale participation data with which to model their effects. Indeed, Mendelsohn and Markowski (1999, p. 287) themselves remarked on the need for "further empirical studies with more disaggregated data." de Freitas (2005) has also highlighted the lack of empirical evidence with regard to the relationships among weather, climate, and ORT activity and the necessity of better quantifying these relationships before the potential impacts of climate change for ORT can be understood, explained, and, ultimately, predicted.

The analyses of the significant influences on daily skiing activity for the two ski resorts presented here represent the first known attempt to model ski activity at such a fine temporal and spatial resolution and, thus, offer a significant addition to and improvement on previous studies. Specifically, the purpose of the article is to quantify the influence of weather variations on downhill ski lift ticket sales in Michigan. Such analyses provide the first step in modeling the implications of climate change for this activity and industry sector. As stressed above, understanding current relationships is a vital precursor to the projection of the future impacts of changing conditions (climatic and otherwise) and, ultimately, to the advising of ORT stakeholders regarding the adoption of appropriate climate change adaptation strategies. As such, the analyses presented are of both methodological and practical significance since they illuminate the underlying empirical work necessary to enable the formulation of climate change–related planning and policy recommendations for the ORT industry.

Method

Study Area

The climate of the Great Lakes region in which Michigan is situated is characterized by warm summers, cold winters, and substantial year-round precipitation. Average January temperatures in Detroit, Michigan, the major urban center in the state, range from a high of approximately –1.1°C to lows of less than –6.7°C (Sousounis and Albercook 2000a). The state is classified as Dfa/Dfb (hot–warm summer continental climate) according to the Köppen scheme. The Great Lakes themselves have significant impacts on local and regional conditions; areas leeward of the lakes experience intense lake-effect storms, and lake-effect snow currently contributes up to 50% of annual snowfall in these areas (Sousounis and Albercook 2000a).

The state of Michigan is home to more than 40 downhill ski resorts and has been named the Midwest's premier ski destination by *Ski* magazine (Michigan Economic Development Corporation 2007). While the majority of the state's population resides in the southern portion of the Lower Peninsula of the state (in cities such as Detroit, Grand Rapids, and [East] Lansing), most of the ski resorts are situated in the northern portion of the Lower Peninsula and in the Upper Peninsula. Michigan can be considered a regional ski destination, attracting the majority (60% according to a 2000 survey) of its visitors from within the state, with the remainder traveling in from the surrounding states of Wisconsin, Illinois, Indiana, and Ohio and the adjoining Canadian province of Ontario (Stynes and Sun 2001). According to the 2000 survey, approximately 54% of ski trips within or to the state are day visits, with the other 46% being overnight trips. Of these overnight trips, nearly 90% last 1 to 3 nights, with the distribution of lodging type as follows: 28% hotel at ski resort, 35% hotel in area, 20% seasonal home, and 17% visiting friends and relatives. Approximately 90% of active visitors to Michigan's ski resorts consider themselves primarily downhill skiers, while 10% consider themselves primarily snowboarders (Stynes and Sun 2001).

Two popular ski resorts in the northwestern part of lower Michigan served as the two case study sites. For their anonymity (because of the proprietary nature of their daily sales records), they will be referred to only as Ski Area I and Ski Area II in this article. While the sites are located close to one another, there are distinct differences between them. Ski Area I is larger in scale and offers high-end, resort-like lodging facilities. Ski Area II is smaller and has a moderate lodging facility. Ski Area I generally attracts more long-distance and overnight visitors than does Ski Area II. Daily adult lift ticket prices in 2005-2006 were $40/$45 (weekday/weekend) at Ski Area I and $32/$39 at Ski Area II.

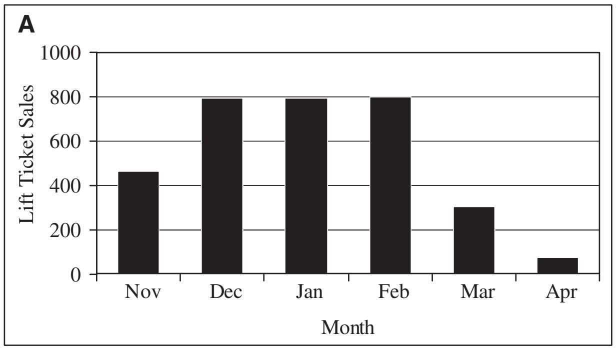
It should be noted that a larger number of case study sites was hoped for by the researchers. However, as described in further detail in Nicholls and Holecek (forthcoming) as well as in the concluding section of this article, participation and sales data are notoriously difficult to acquire from commercial ORT operations, particularly at the daily level needed here. Indeed, of the 37 ski resorts contacted and asked to participate in the study, only 9 recorded the number of lift tickets sold per day (as opposed to per month or year), of which 4 were willing to share these data, and only 2 could offer a time series of sufficient length for the regression procedures employed in the analyses.

Conceptual Model and (In)dependent Variables

Based on a review of the literature and discussion with ski area operators, the relationship between ski participation and its explanatory factors may be expressed as ski participation = f (weather, prices, economic conditions, leisure time, etc.). Standard multiple regression with ordinary least squares and simultaneous entry of all independent variables was applied, where the number of daily lift tickets sold per day was regarded as the dependent or outcome variable. Sales of season passes were excluded since data concerning the actual use of these passes on a daily basis were not available. The average number of lift ticket sales per month for the years for which daily sales data were available for each area is illustrated in figure 1. As shown, sales were substantially higher during certain months than others. Downhill skiing, as is true for many ORT businesses, exhibits a distinct peak and off-peak business pattern. Anecdotal evidence gathered from the ski facility managers also suggested that weather conditions, as well as other factors, have different impacts on peak and off-peak sales. As a result, two separate models were constructed for each area, one for the peak season (defined as December, January, and February) and one for the off-peak season (November, March, and April; Ski Area II typically closes at the end of March, so no April data were available for this resort). This approach allowed the effects of the independent variables on lift ticket sales to be ascertained for both the peak and off-peak ski seasons for each resort. Moreover, prior testing of this two-season approach versus a single season approach using a dummy variable to represent peak months revealed the former to result in better performing models. Table 1 lists the independent variables tested in the analyses as well as the expected sign on each coefficient.

Five daily weather variables were available for inclusion in the regressions: maximum temperature, minimum temperature, snowfall, snow depth, and wind chill (as recorded at the nearest weather station). Maximum and minimum temperatures are the highest and lowest temperatures recorded in a given 24-hour period at a specified location and are measured in degrees Fahrenheit. Snowfall is defined as the amount of snow that has fallen during the preceding 24-hour measurement period, while snow depth is the total amount of snow on the ground at the time of measurement; both are measured in inches. Since colder weather usually facilitates snow and prevents snow from melting, it was

Figure 1
Average Monthly Lift Ticket Sales for (a) Ski Area I and (b) Ski Area II



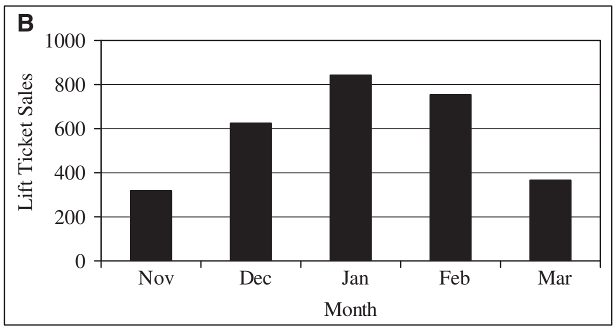


Table 1
Independent Variables Tested in Regression Analyses and Expected Sign of Coefficient

Independent Variable	Temporal Resolution	Expected Sign
Maximum temperature	Daily	Negative
Minimum temperature	Daily	Negative
Local snow depth	Daily	Positive
Local snowfall	Daily	Positive
Wind chill	Daily	Positive
SW MI snow depth	Daily	Positive
SW MI snowfall	Daily	Positive
SE MI snow depth	Daily	Positive
SE MI snowfall	Daily	Positive
Gas price	Weekly	Negative
Consumer Confidence Index	Monthly	Positive
Price of lift ticket	Annual	Negative
Number of runs	Annual	Positive
Weekend	Dummy	Positive
Holiday	Dummy	Positive
Year	Dummy	Positive

Note: SW MI = southwest Michigan; SE MI = southeast Michigan.

theorized that maximum and minimum temperatures would each have a negative impact on lift ticket sales, meaning higher temperatures would result in a decrease in sales. On the contrary, increases in snowfall and snow depth were expected to affect lift ticket sales positively. Wind chill is a measure of the effect of wind speed on our perception of cold. The higher the wind chill, the less cold it seems; thus, one would expect a positive relationship between wind chill and ski activity. It was also hypothesized, on the suggestion of the ski area managers, that snow conditions in skiers' areas of origin positively affect participation; that is, residents of southern Michigan and other origin markets are more likely to ski at northern resorts once they have experienced snow at home. Snow conditions for the Detroit and Grand Rapids areas, two major sources of visitors to the resorts studied, were therefore also included as independent variables.

Prices and income have been identified as the two most common explanatory factors in previous research on the demand for tourism and recreation activities (Crouch 1994; Lim 1997). In this study, gasoline prices, indicating the cost of transportation, and the price of a standard ski lift ticket were included in the analysis. Increases in gas and lift ticket prices were expected to have negative effects on lift ticket sales. The Consumer Confidence Index (CCI), which measures consumers' perceptions of current economic conditions, was included to represent the income factor. It was assumed that ticket sales would increase during better economic conditions.

Beside the continuous independent variables described above, the use of categorical, or dummy, variables was necessary to control for several other factors. To account for the daily variation in lift ticket sales, it was important to control the weekend factor since most people work Monday through Friday and have more leisure time for recreational activities during weekends. As can be seen in figures 2 and 3, more lift tickets were purchased on weekends than on weekdays for the peak and off-peak seasons at both ski facilities. As a result, the dummy variable "weekend" was created, with 1 representing Saturday and Sunday and 0 representing Monday through Friday.

Another dummy variable, "holiday," was added to the peak season models to recognize the days between Christmas and New Year's Day, the busiest period of the year for Michigan ski area operators. While the off-peak season does include the long Thanksgiving weekend, a holiday dummy variable was not included in the off-peak models because of inconsistencies in the annual opening date of the ski facilities (often after Thanksgiving). Furthermore, the weekend variable was expected to capture the majority of variation in lift ticket sales that occurred on those Thanksgivings that the resorts were open. "Year" is an annual time trend dummy variable aimed at capturing the factors in time-series data unaccounted for by the other

Figure 2
Average Daily Lift Ticket Sales during Peak Season (December, January, February) for (a) Ski Area I and (b) Ski Area II

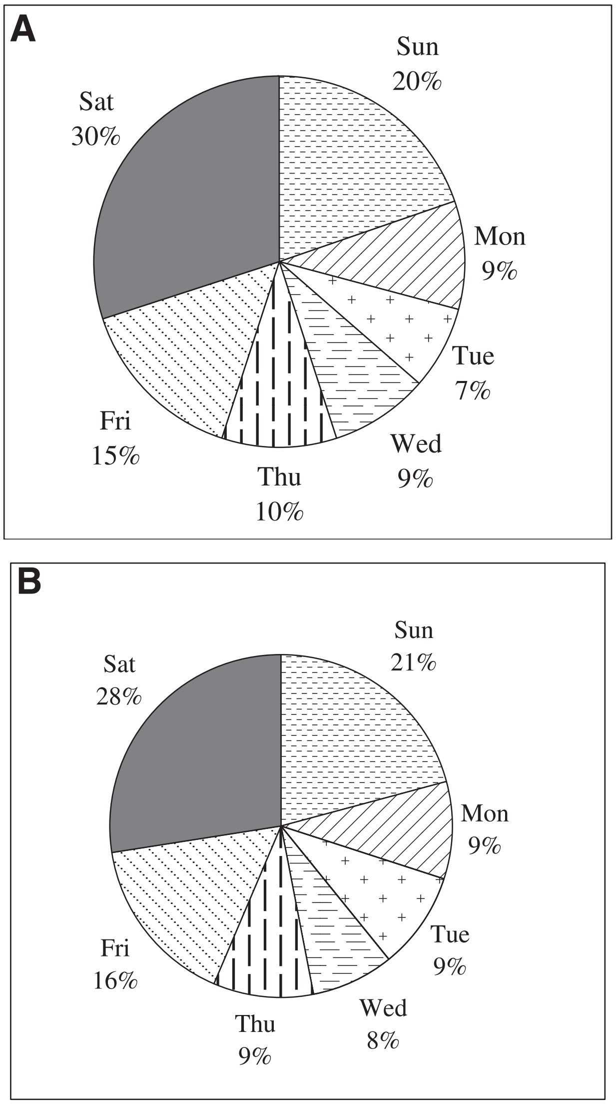
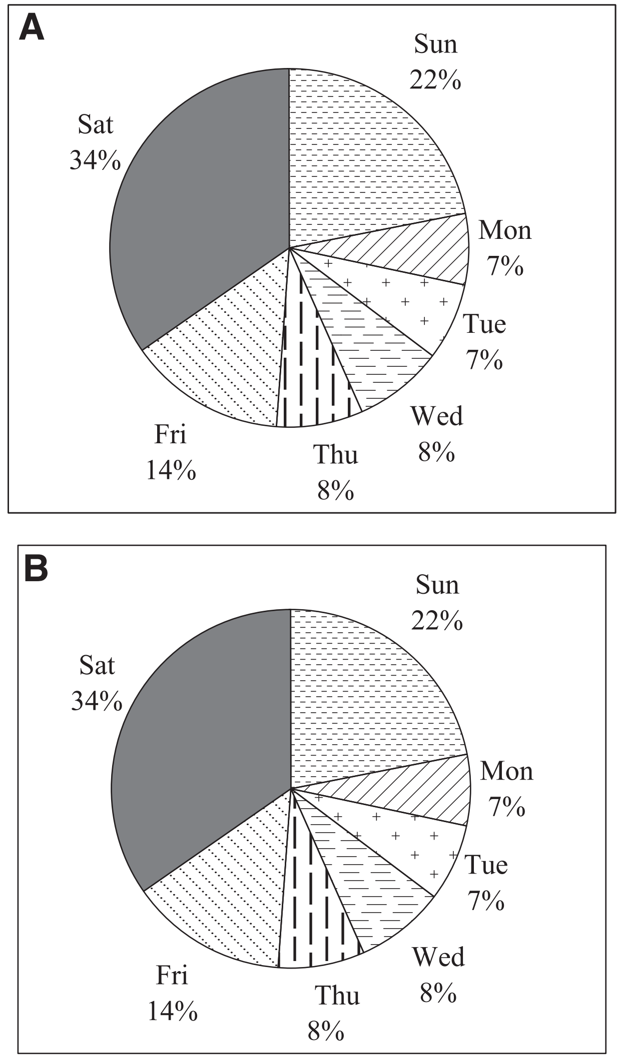


Figure 3
Average Daily Lift Ticket Sales during Off-Peak Season (November, March, April) for (a) Ski Area I and (b) Ski Area II



independent variables. A final dummy variable added was "number of runs," accounting for the changes in capacity of the ski areas over the time span of the data sets.

Functional Form

Linear models, indicating a linear relationship between the explanatory variables and daily lift ticket sales, were first applied. To test for nonlinear relationships, other functional forms were then tested, including semilog, exponential, and double log. Among these forms, the exponential model, in which the logarithm of daily lift ticket sales served as the dependent variable, performed the best (based on comparison of R^2 values), and only this form is considered in any further detail in this article. The exponential form is also preferred since it enables the coefficients on the independent variables to be interpreted as percentage rather than absolute changes in the dependent variable.

A spline function was also employed to test whether a threshold temperature exists. Although lower temperatures are necessary to enable skiing, it was hypothesized that there may be a certain temperature below which conditions become so cold that they deter people from going skiing. The spline approach enables testing for threshold temperatures, when the value of the coefficient estimate starts to change (Greene 2003). An additional term, $D(T^* - \text{Min. Temp})$ was added to the equation, where T^* is the preset threshold temperature and D is 1 when the minimum temperature is below T^* and 0 otherwise. This equation was tested multiple times while resetting the value of T^* in each of the four regression models to examine whether, and, if so, at what temperature, a threshold existed in the data.

Sources of Data

All the dependent and independent variables were collected in the form of secondary data. Eight years of daily lift ticket sales data were obtained from Ski Area I, and 18 years of data were obtained from Ski Area II. Local weather data were retrieved from the weather recording stations closest to the locations of the two sites. Additional snow depth and snowfall data were also collected from stations in the Detroit and Grand Rapids areas, representing snow conditions in the southern and more populous part of the state from where the majority of visitors arrive. Gas prices were obtained from the American Automobile Association, and CCI values were obtained from the Conference Board. While all the weather variables were available in a daily format, gas prices were reported weekly, CCI was available monthly, and lift ticket price and number of runs (acquired from the resorts themselves) changed only from year to year. To construct a daily model, the values of these variables were therefore duplicated to represent all the days in the corresponding periods. While not ideal, this was the only option available without excluding these potential explanatory factors.

Findings

Prior to the running of the four regression analyses (two seasons for each of the two courses), the independent variables were examined for multicollinearity, a violation of the assumptions of multiple regression techniques. Tolerance levels close to 0 and variance inflation factors (VIFs) greater than 10 were used to identify problematic relationships among the variables. As a result, the variables representing the prices of lift tickets and gas, and the number of runs, were excluded from all four models. VIFs for the remaining variables are reported for each model in the results tables presented below, and all fall within the acceptable range. As noted above, the models presented are of the exponential form, in which the logarithm of daily lift ticket sales serves as the dependent variable.

Ski Area I

Results of the regression analyses for Ski Area I for the peak ($R^2 = .559$) and off-peak ($R^2 = .587$) seasons are presented in tables 2 and 3, respectively. In the peak season model, a total of five variables—local minimum temperature, local snow depth, consumer confidence, holiday, and weekend—were found to exhibit a significance level of .05 of better. The coefficient on minimum temperature was negative ($t = -2.10$, $p \leq .05$), suggesting a 1% decrease in lift ticket sales with each 1°F increase in minimum temperature, whereas the coefficient on snow depth was positive ($t = 4.96$, $p \leq .01$), indicating an 8% increase in daily lift ticket sales with each additional inch of snow. The other significant explanatory variables were all of a positive nature, suggesting substantial increases in lift ticket sales with increases in consumer confidence ($t = 2.96$, $p \leq .01$), during the Christmas–New Year holiday ($t = 13.73$, $p \leq .01$), and on weekends ($t = 13.51$, $p \leq .01$).

In the off-peak model, four variables—maximum temperature, snow depth, weekend, and year—were found to be statistically significant. Each 1°F increase in maximum temperature was associated with a 5% decline in lift ticket sales ($t = 3.78$, $p \leq .01$), while each additional inch of snow resulted in an increase in sales of 7% ($t = 2.17$, $p \leq .05$). The other two significant influences on daily lift ticket sales in the off-peak model for Ski Area I were the dummy variables representing weekends ($t = 7.11$, $p \leq .01$) and the year ($t = 2.27$, $p \leq .05$); in both cases, a positive relationship was observed, indicating increases in lift ticket sales on weekends and from year to year.

Ski Area II

Tables 4 and 5 illustrate results of the regression analyses for the peak ($R^2 = .445$) and off-peak ($R^2 = .5597$) seasons, respectively, for Ski Area II. In the peak season, five significant influences on daily lift ticket sales emerged, including two weather-related variables, maximum temperature and snow depth, as well as the variables representing holidays, weekends, and the year. Each 1°F increase in maximum temperature was associated with a 1% decline in sales ($t = -3.21$, $p \leq .01$), while each additional inch of snow generated an additional 7% in sales ($t = 11.01$, $p \leq .01$). The other significant explanatory variables were all of a positive nature, suggesting substantial increases in lift tickets sales during the Christmas–New Year holiday ($t = 18.00$, $p \leq .01$), on weekends ($t = 21.79$, $p \leq .01$), and from year to year ($t = 3.07$, $p \leq .01$).

Table 2
Results of Regression Analysis for Ski Area I for Peak Season, 1996–2004

	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics
Explanatory Variable	*B*	*SE*	β	*t*	VIF
Constant	–128.69	83.02	—	—	—
Max temp	–0.01	0.01	–.09	–1.45	2.82
Min temp	–0.01*	0.00	–.12*	–2.10*	2.45
Snow depth	0.08**	0.02	.27**	4.96**	2.26
Snowfall	0.004	0.05	.00	0.09	1.64
Wind chill	0.005	0.00	.06	1.28	1.44
SW MI snow depth	–0.01	0.01	–.03	–0.43	3.88
SW MI snowfall	–0.06	0.04	–.09	–1.54	2.60
SE MI snow depth	–0.02	0.02	–.10	–1.59	3.11
SE MI snowfall	0.02	0.04	.02	0.40	1.84
CCI	0.02**	0.01	.15**	2.96**	1.90
Holiday	1.81**	0.13	.53**	13.73**	1.11
Weekend	1.22**	0.09	.51**	13.51**	1.05
Year	0.07	0.04	.08	1.58	1.93

Note: VIF = variance inflation factor; CCI = Consumer Confidence Index; SW MI = southwest Michigan; SE MI = southeast Michigan. Dependent variable = logarithm of daily lift ticket sales. R^2 = .559, n = 656, F = 32.1**.
*Significant at the 5% level. **Significant at the 1% level.

Table 3
Results of Regression Analysis for Ski Area I for Off-Peak Season, 1996–2004

	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics
Explanatory Variable	*B*	*SE*	β	*t*	VIF
Constant	–566.76	251.51	—	—	—
Max temp	–0.05**	0.01	–.44**	–3.78**	3.63
Min temp	–0.004	0.01	–.04	–0.32	3.57
Snow depth	0.07*	0.03	.24*	2.17*	3.23
Snowfall	0.02	0.08	.02	0.24	1.49
Wind chill	–0.0003	0.01	–.003	–0.04	1.70
SW MI snow depth	–0.01	0.04	–.02	–0.19	2.87
SW MI snowfall	–0.06	0.08	–.06	–0.72	2.03
SE MI snow depth	0.06	0.06	.07	0.96	1.47
SE MI snowfall	0.15	0.16	.08	0.98	1.72
CCI	–0.01	0.02	–.08	–0.64	4.39
Weekend	1.19**	0.17	.45**	7.11**	1.11
Year	0.29*	0.13	.27*	2.27*	3.90

Note: VIF = variance inflation factor; CCI = Consumer Confidence Index; SW MI = southwest Michigan; SE MI = southeast Michigan. Dependent variable = logarithm of daily lift ticket sales. R^2 = .587, n = 277, F = 13.3**.
*Significant at the 5% level. **Significant at the 1% level.

In the off-peak season, six variables were significant: minimum temperature, snow depth, wind chill, consumer confidence, weekend, and year. The relationship between lift ticket sales and minimum temperature was negative (t = 3.79, $p \leq .01$), while that between ticket sales and snow depth was positive (t = 8.00, $p \leq .01$), suggesting a 2% decline and 9% increase in sales with each additional degree Fahrenheit of minimum temperature and inch of snow, respectively. The influence of wind chill was also positive (t = 2.75, $p \leq .01$), with each

Table 4
Results of Regression Analysis for Ski Area II for Peak Season, 1985–2003

	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics
Explanatory Variable	*B*	*SE*	β	*t*	VIF
Constant	–35.81	13.52	—	—	—
Max temp	–0.01**	0.004	–.12**	–3.21**	2.69
Min temp	–0.001	0.003	–.02	–0.57	2.63
Snow depth	0.07**	0.01	.30**	11.01**	1.53
Snowfall	–0.03	0.03	–.03	–1.17	1.31
Wind chill	0.001	0.002	.01	0.29	1.90
SW MI snow depth	–0.003	0.01	–.01	–0.36	2.92
SW MI snowfall	–0.02	0.02	–.02	–0.88	1.63
SE MI snow depth	0.01	0.01	.03	0.90	2.27
SE MI snowfall	0.02	0.03	.02	0.69	1.32
CCI	–0.001	0.001	–.03	–1.09	1.64
Holiday	1.32**	0.07	.41**	18.00**	1.08
Weekend	1.08**	0.05	.49**	21.79**	1.05
Year	0.02**	0.01	.09**	3.07**	1.62

Note: VIF = variance inflation factor; CCI = Consumer Confidence Index; SW MI = southwest Michigan; SE MI = southeast Michigan. Dependent variable = logarithm of daily lift ticket sales. R^2 = .445, n = 1,493, F = 71.0**.
**Significant at the 1% level.

Table 5
Results of Regression Analysis for Ski Area II for Off-Peak Season, 1985–2003

	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics
Explanatory Variable	*B*	*SE*	β	*t*	VIF
Constant	–147.75	26.22	—	—	—
Max temp	–0.01	0.01	–.08	–1.27	2.43
Min temp	–0.02**	0.01	–.24**	–3.79**	2.46
Snow depth	0.09**	0.01	.40**	8.00**	1.50
Snowfall	0.02	0.05	.02	0.43	1.30
Wind chill	0.01**	0.01	.15**	2.75**	1.73
SW MI snow depth	0.01	0.03	.03	0.48	2.61
SW MI snowfall	–0.04	0.05	–.04	–0.72	1.87
SE MI snow depth	0.02	0.04	.03	0.58	1.76
SE MI snowfall	0.05	0.10	.02	0.46	1.62
CCI	–0.005*	0.002	–.11*	–2.31	1.49
Weekend	1.03**	0.09	.50**	11.67**	1.09
Year	0.08**	0.01	.29**	5.81**	1.45

Note: VIF = variance inflation factor; CCI = Consumer Confidence Index; SW MI = southwest Michigan; SE MI = southeast Michigan. Dependent variable = logarithm of daily lift ticket sales. R^2 = .559, n = 352, F = 27.9**.
*Significant at the 5% level. **Significant at the 1% level.

one unit increase in wind chill associated with a 1% increase in lift ticket sales. The relationship between consumer confidence and lift ticket sales was negative, suggesting a decline in sales with increasing consumer confidence ($t = -2.31$, $p \leq .01$). The other two significant influences on daily lift ticket sales in the off-peak model for Ski Area II were the dummy variables representing weekends (t = 11.67, $p \leq .01$) and the year (t = 5.81, $p \leq .01$); in both cases, a positive relationship was observed, indicating increases in lift ticket sales on weekends and from year to year.

Discussion

The findings presented above include some reassuring consistencies as well as some interesting differences between the two seasons and two ski areas analyzed. The models for Ski Area I performed better than those for Ski Area II, particularly in the peak season. A possible explanation for this difference may be that since Ski Area I attracts more out-of-town rather than local visitors, its lift ticket sales may be more sensitive to the independent variables entered into the regression analyses. Alternatively, one or more other unanticipated differences in the characteristics of the two resorts not incorporated in the regressions may account for the differential found. Further discussion of the variables not considered in the analyses because of either their unavailability or measurement difficulties is provided below.

With respect to the local weather variables entered into the regressions, the only variable to consistently reach statistical significance was snow depth. In all four cases, this variable had a positive impact on sales, as anticipated since sufficient snow is a vital prerequisite of any ski activity. Snowfall, in contrast, did not ever reach significance, suggesting that the base of snow on the ground has a greater influence on daily lift ticket sales than the amount of recent snowfall, at least at the two resorts studied. It is important to note that both ski facilities have installed snowmaking technologies that reduce their dependence on natural snowfall; however, the snowfall and snow depth variables employed in the regression analyses reflect conditions at the local weather station rather than on the slopes themselves. Thus, they represent only natural snow accumulation.

The impact of temperature on lift ticket sales was somewhat inconsistent. In all four cases, one of the two temperature variables was significant and, as expected, of a negative nature, suggesting increases in lift ticket sales with declines in temperature. However, although minimum temperature was the significant factor in the peak season at Ski Area I while maximum temperature was significant in the off-peak season, the reverse occurred at Ski Area II; that is, maximum temperature was significant in the peak season, while minimum temperature dominated in the off-peak season. The testing of threshold minimum temperatures below which conditions became too uncomfortable to ski in the peak season (and coldest) months was not successful for either ski area. Despite multiple trials setting hypothetical minimum temperature thresholds at consistently declining levels, no such point was discovered within the range of the two data sets. The temperatures during the shoulder months did not drop low enough to make such testing applicable. It is possible that some of this effect may have been captured instead by the wind chill variable. However, wind chill was significant in only one of the four models.

The variables entered into the regressions to account for weather conditions in the southern portion of the state, at two major origin areas for visitors to the resorts studied, failed to reach statistical significance in any instance. Thus, it would appear that, contrary to the opinion of ski industry members, weather conditions in visitors' downstate home areas do not have any discernible effect on upstate ski activity, at least in the case of the two resorts studied. This is perhaps consistent with the increasing availability of options via which potential skiers can check the weather information and ski conditions at distant ski areas (e.g., on the Internet), thereby reducing the influence of conditions in their home areas. This does nevertheless leave open the issue of what, if any, particular conditions or events precipitate skiers' first trips to the slopes each annum, a question that is perhaps better approached using a qualitative methodology and that was beyond the scope of the study described here.

Economic conditions, as measured by the CCI, had a significant influence on lift ticket sales in two instances; this effect was positive, as expected, in one case but negative in the other. However, though statistically significant, this negative impact during the off-peak season at Ski Area II was relatively minor, indicating a decrease in sales of 0.5% with each unit increase in consumer confidence. This suggests that the two resorts studied are perhaps somewhat impervious to economic shifts and, given the state of Michigan's relatively poor economic performance in recent years, indicates a certain level of resiliency in ski activity to economic downturn, particularly in the peak ski months. By far the greatest influences on daily lift ticket sales at both ski areas and in both seasons were the two temporal variables, namely, time of the week and holidays (peak season only since no holidays fell in the off-peak months). As expected, sales saw significant increases on all holidays and weekends. The variable representing the year was significant in both seasons at Ski Area II but only in the off-peak season at Ski Area I. This suggests that while the second resort is still experiencing annual increases in daily lift ticket sales throughout the entire operating season, the first resort may have reached maximum capacity in the peak season months. Alternatively, it might represent competition from other resorts that is stymieing continued growth in peak season sales. Growth in the off-peak season at Ski Area I was substantial, however, perhaps reflecting recent efforts to improve the price and/or quality of off-peak season offerings as well as to increase and/or improve the level of marketing of these offerings.

In summary, in each case where a variable reached statistical significance, the direction of the relationship indicated was of the nature anticipated, and, while many variables did not reach significance at all, no completely unexpected findings were recorded. However, while approximately 45% to 60% of the variation in daily lift ticket sales was explained by the four models developed, this does still leave 40% to 55% of the fluctuation not captured by the independent variables tested. It is possible that various other factors, such as regular ongoing or special, one-time marketing campaigns, competition between resorts, the opening of new or improved facilities (e.g., new runs or lifts, lighting to enable nighttime activity), and special promotions or events, have substantial positive impacts on ski participation. Conversely, factors such as poor road conditions might have negative impacts on activity, particularly for day visitors with short planning horizons. However, such factors can be very difficult to operationalize as independent variables suitable for use in multiple regression analysis, particularly at the daily level adopted in this study, and, as a result, they could not be considered here. Furthermore, some potential influences are likely to exhibit strong collinearity with other independent variables. In this study, for example, several factors, specifically the prices of lift tickets and gas and the number of runs at each resort, had to be excluded because of collinearity issues.

In light of the above, future research efforts might include the exploration of alternative modeling techniques as well as the continued search for additional quantifiable independent variables so as to improve the performance of models such as those developed in this study. Furthermore, future research should also be extended to additional sites, in Michigan, other U.S. states, and other countries. Since the analyses presented here were conducted using data from only two ski areas, the results cannot be generalized to other ski resorts. Nevertheless, the study does provide a methodological approach that could be applied to other ski areas, subject to the acquisition of the necessary dependent and independent variable data. The opportunity to compare and contrast the similarities and differences in results across a larger number of ski areas would be of interest both methodologically and from a practical perspective.

However, despite the limitations associated with this study, it does nevertheless provide unique new findings regarding the influence of weather variability on ski activity and sets the stage for further refinement of the methods utilized so as to develop models of the relationships among skiing, weather, and climate on which projections of the potential impacts of climate change on the ski sector can then be made. Given the size of the ski industry in Michigan, in the United States, and internationally, such research is extremely crucial if the industry is to recognize and respond to this phenomenon in a timely manner. As suggested by Elsasser and Bürki (2002), these adaptation strategies are likely to range from the maintenance of the ski industry in its current form via the (increased) adoption of artificial snowmaking technologies or, where physically possible, (increased) development of ski operations at higher elevations; to the provision of government subsidies to ski operations; to the development of alternatives to ski tourism (e.g., by diversifying into the provision of summertime activities such as hiking and golf); to, in the worst-case scenario, the abandonment of ski operations altogether.

Projections suggest that the Great Lakes climate will become warmer and wetter in the future. Minimum and maximum winter temperatures are estimated to rise by between 0.5ºC and 6ºC and by between 0.5ºC and 3ºC, respectively, by 2025 to 2034, the variation being accounted for by differences in the climate model utilized. By 2090 to 2099, average winter temperatures are projected to increase by 4ºC to 7ºC (Sousounis and Albercook 2000b). Of crucial relevance to the region's winter tourism industry, what is now considered a "normal" winter in terms of temperature and snowfall may represent the most extreme winter conditions by the end of the 21st century. By this period, total snowfall may be halved, with a significant reduction in lake-effect snow (Sousounis and Albercook 2000b).

The implications of such changes for Michigan's winter sports industries are profound. While the development of ski operations at higher elevations is not a feasible option because of the state's natural terrain and subsidization is exceedingly unlikely, the consistent significance of snow depth in the regression models developed suggests that the (increased) adoption of snowmaking technologies would seem to be a more viable and worthwhile strategy, subject to the necessary environmental considerations such as water and energy use.

The ability to successfully adapt to climate change in Michigan and beyond is also likely to depend on the nature of individual resorts. For example, larger ski operations, such as Boyne USA, Intrawest, and the American Skiing Company, have already responded to multiple pressures including those exerted by the threat of climate change through the considerable diversification of their portfolios, and they now boast activities such as golf, hiking, mountain biking, real estate opportunities, and year-round conference facilities in addition to the traditional winter season offerings. Well-capitalized corporations are also much better placed to absorb a year or two of inadequate weather conditions satisfactorily, whereas smaller operations are considerably more vulnerable and may be financially devastated by even one poor season. Thus, if recent trends in winter temperatures and snow fall continue, these negative impacts on small to medium-sized family owned and operated ski resorts may well be seen sooner rather than later throughout the industry. In the meantime, the Keep Winter Cool campaign, a partnership between the National Ski Areas Association and the Natural Resources Defense Council, will continue to raise public awareness and understanding of global warming and highlight opportunities to mitigate this phenomenon (www.keepwintercool.org). Investigation of the reactions of winter recreation enthusiasts to projected changes in ski conditions such as those suggested for Michigan above is an additional worthwhile avenue of future research. Such an analysis might be conducted using a qualitative approach or the contingent behavior analysis techniques employed by Richardson and Loomis (2005) in their study of the likely impacts of climate change on visitation to Colorado's Rocky Mountain National Park.

Conclusion

The results of this study suggest that the weather, as measured by minimum or maximum temperature, snow depth, and wind chill, does indeed have a statistically significant impact on downhill ski lift ticket sales in Michigan. Significant results from the four regression analyses reported herein are summarized in table 6. As expected, the snow depth variable was found to be significant in all four models, with only one additional inch of snow depth producing a 7% to 9% increase in daily lift ticket sales. Sales were also influenced by one of the two local temperature variables in each of the four models; an increase in temperature was found to have a consistently negative impact on sales. Wind chill proved to be significant in only one of the four regressions, suggesting that advances in ski apparel may have largely mitigated this measure as a factor in skiers' behaviors. The ski area managers' contention that snow conditions in the lower region of the state from which they draw a large number of their customers matter was not supported in these analyses since none of the relevant variables were found to be statistically significant. The results were also consistent for the weekend and holiday variables, confirming that increased lift ticket sales occur when people have more leisure time. In comparing results for the peak and off-peak models, only slight differences were evident, and no consistent patterns were found. Nevertheless, this peak–off-peak modeling strategy was found to be superior to a single-season approach, resulting in better performing models and improved projections of sales.

Table 6
Summary of Statistically Significant Regression Results for Ski Areas I and II, Peak and Off-Peak Seasons

	Unstandardized Coefficients (*B*)			
Explanatory Variable	Ski Area I, Peak	Ski Area I, Off Peak	Ski Area II, Peak	Ski Area II, Off Peak
Max temp	—	–0.05**	–0.01**	—
Min temp	–0.01*	—	—	–0.02**
Snow depth	0.08**	0.07**	0.07**	0.09**
Snowfall	—	—	—	—
Wind chill	—	—	—	0.01**
SW MI snow depth	—	—	—	—
SW MI snowfall	—	—	—	—
SE MI snow depth	—	—	—	—
SE MI snowfall	—	—	—	—
CCI	0.02**	—	—	–0.005*
Holiday	—	N/A	1.32**	N/A
Weekend	1.81**	1.19**	1.08**	1.03**
Year	1.22**	0.29*	0.02**	0.08**
R^2	.559	.587	.445	.559

Note: CCI = Consumer Confidence Index; SW MI = southwest Michigan; SE MI = southeast Michigan. Dependent variable = logarithm of daily lift ticket sales.
*Significant at the 5% level. **Significant at the 1% level.

While the lack of any existing similar research does not allow for comparison with other study areas, it is reasonable to anticipate that the directions of relationships found are likely to hold at other ski destinations, though our findings also suggest that the exact patterns and magnitudes of these relationships might vary. The clear articulation of the magnitudes and directions of the relationships between ORT activity or sales (whether of skiing or otherwise) and weather conditions is of great interest and utility to both ORT researchers and providers. For ORT providers and other industry stakeholders, in this case the managers of the ski resorts analyzed, our analyses provide firm empirical evidence regarding the direct impacts of weather conditions on daily operations, as opposed to the anecdotal stories and individual experiences on which they have previously had to rely. Such knowledge may also help ORT owners and operators to conduct their businesses more efficiently, especially because of the utility of the information provided for short-term planning and management. For example, empirical models of the historical relationships between ORT participation and variations in climatic, economic, and temporal factors could aid short-term decisions regarding purchasing, hiring, and staffing requirements.

Furthermore, understanding of the relationships between weather conditions and ski activity as identified by the models presented here provides the basis for further investigation of the potential impacts of future climate variability and change on the ski industry. For example, examination of the effect of increasing minimum and maximum temperatures above their historical means would reveal the likely outcomes of the warmer conditions predicted by most climate scientists. Combination of these models with a range of climate change scenarios—which account for not only potential changes in climate but also variations in key demographic, socioeconomic, and technological trends (IPCC 2007)—would enable longer-term projections to be made. In turn, provision of such projections would enable the ORT industry to begin seriously considering appropriate adaptation strategies. For example, while both resorts studied have already installed snowmaking equipment to help guarantee adequate snow during peak ski months, snowmaking currently requires certain criteria such as suitably low temperatures to be met. Thus, climate change may threaten this activity, requiring either the development of less temperature-dependent snowmaking technologies or more dramatic strategies such as a switch in emphasis from winter to spring, summer, and fall product offerings.

As a final note, the study on which the results presented here were predicated provided ample evidence regarding the continuing issue of access by researchers to commercial tourism entities' proprietary data. As previously noted by Echelberger and Shafer (1970, p. 391), the development of sound models that "define more precisely than intuitive hunches what variables" are related to the use of recreation sites and resources requires access to accurate use data as well as the ability to measure those variables suspected of influencing variations in use. As these authors go on to state, "Publicly financed research can assist the private sector only to the extent that the private sector is willing to cooperate" (p. 391). As their and our results demonstrate, the development of good working models of ski activity is technically feasible. Thus, given the gravity of the climate change phenomenon, it would appear to behoove the ski industry not only to keep better track of their daily activity levels but also to be willing to share these data with research teams capable of analyzing their individual situations and developing practical recommendations with regard to potential adaptation techniques.

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