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The Impact of Climate Change on Golf Participation in the Greater Toronto Area (GTA): A Case Study

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Golf is identified as a large recreation industry that is particularly sensitive to weather and climate, yet research assessing the direct relationship between them is extremely limited. Consequently, the potential implications of climate change for the industry remain largely unexamined. This case study presents findings of an analysis of the influence of weather conditions on the number of rounds played at a golf course in the Greater Toronto Area (GTA) of southern Ontario (Canada). An empirical relationship between daily rounds played and weather variables, derived through multiple regression analysis, was then used to examine the potential impacts of two climate change scenarios on the length of the golf season and the number of rounds played in the 2020s, 2050s and 2080s. The model projected that as early as the 2020s the average golf season could be one to seven weeks longer and with much improved shoulder seasons annual rounds played could increase 5.5% to 37.1%. The model results for the warmer long-term climate change scenario (2080s) were very similar (average golf season within 3% and average rounds played within 2%) to a spatial climate analogue (Columbus, Ohio).

KEYWORDS: *Golf, climate change, Canada, recreation, environment.*

Introduction

Weather and climate have a major influence on the outdoor recreation sector, including the length and quality of recreation seasons. The impact of the 2002 drought and wildfires on park visitation, fishing and rafting in the State of Colorado (Butler, 2002), reductions in boating opportunities on the Great Lakes from lower than normal water levels in 1999 to 2001 (Environment Canada, 2003), and the shortened ski seasons in the US Midwest from 1996-1999 (Scott, 2005) are just three recent examples. Despite the importance of weather and climate to outdoor recreation, the sensitivity of individual recreation industries to climate variability has not been adequately assessed (de Freitas, 2003; Scott, McBoyle, & Mills, 2003; Wall, 1992). Understanding of the potentially important implications of global climate change for the outdoor recreation sector also remains very limited (Intergovernmental Panel on Climate Change, 2001; Scott, McBoyle, & Schwartzentruber, 2004; Wall, 1992).

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TABLE 1
Recent Media Depictions of Weather and Climate Impacts on the US Golf Industry

Date of Headline	Newspaper Headline	U.S. Region
02/06/2003	Fickle weather puts a damper on area golf	Gulf coast
03/03/2003	100-year drought causes Denver municipals to close	Southwest
06/11/2003	Impact of foul weather on area golf course facilities varies	Northeast
06/17/2003	Cool weather cuts into swing of things at golf courses	Upper Midwest
08/27/2003	Golfers brave the hot conditions as season nears	Lower Midwest
02/25/2004	Cold weather dampens area participation	Southeast
03/25/2004	Weather damages golf course revenues	Southwest

Source (in order of headline): Harig (2003), Holland (2003), Fogg (2003), Bensen (2003), Domoney (2003), Westin (2004), Stark (2004)

The golf industry is one of the largest recreation sectors in North America and one that is highly influenced by weather and climate. There are approximately 20,000 golf courses (World Golf Foundation, 2001) and some 30 million amateur golfers (Royal Canadian Golf Association, 1999a; World Golf Foundation, 2001) in North America. In 2000, golf accounted for US$62 billion worth of goods and services in the Unites States alone, of which US$20.5 billion in revenues were generated directly at golf facilities, mainly through green fees (World Golf Foundation, 2002). By comparison, the golf sector is estimated to approximate the economic size of the motion picture industry in the United States (US$57.8 billion) (U.S. Census Bureau, 2001).

Before further discussing the sensitivity of the golf industry to weather and climate, it is important to distinguish "weather" from "climate" because the two terms are often erroneously used interchangeably. Weather is defined as the day-to-day conditions of the atmosphere (e.g., sun, cloud, rain and fog, amount of rain, wind speed, temperature and humidity). Weather tends to affect golf on a short-term basis—hourly to daily. For example, the time required for thick morning fog to dissipate could delay a course from opening for hours, while an afternoon thunderstorm could suspend play for several hours because of the threat posed by lightening or by heavy rainfall and standing water. By comparison, climate is defined as the long-term average behavior of weather in a given location (Aguado & Burt, 2004), and generally affects golf on longer temporal scales—weeks, months and years. Climate is a primary determinant of the length of the operating season of a golf course at a given location and has an important influence on golf participation. From a golf operations standpoint, climate also has important implications for irrigation, turf grass selection, and turf disease and pest management.

As evidenced by a range of media headlines, golf industry reports and professional journal articles, the golf industries in the United States and

Canada are very aware of the importance of weather and climate to their business. Table 1 highlights a number of recent newspaper headlines associated with stories about the impact of weather and climate on golf participation in different regions of the United States. According to the *2001 Golf 20/20 Industry Report*, the single most important factor impacting rounds played [both positively and negatively each year] continues to be weather[1] (World Golf Foundation, 2001). In a survey of 2,426 golf courses in the United States, 52% identified climate variability as the leading reason for lower than expected rounds played in 2000 and 2001, while 35% cited climatic variability as the primary reason for higher than expected rounds played (World Golf Foundation, 2004). By comparison, less than 10% of golf courses participating in the same survey identified the economy or course renovations in positively or negatively influencing rounds played. Another analysis of golf participation (1,849 golf courses) in the United States also identified variations in weather[1] as the primary reason for positively (35%) and negatively (62%) affecting annual rounds played in 2003 over 2002 (National Golf Foundation, 2004). Similarly, a recent article in *Golf Business Canada* suggested that "Mother Nature" controls the golf industry in Canada. Based on a survey of golf managers from across Canada, the article concluded that, "there are many things that affect the business of golf, and it is generally acknowledged that weather is one of the more significant factors" (Doey, Wong, & Hun, 2002, p. 12).

It is clear that the North American golf industry attributes a considerable share of its economic success to weather and climate, yet surprisingly very few studies have attempted to assess the empirical relationship between weather and climate and the golf sector. Crowe, McKay, and Baker (1977) were the first to examine this relationship. Focusing on the province of Ontario, Crowe et al. surveyed industry experts in an attempt to identify weather conditions that would define the quality of a day for golf. A "desirable" golf day was defined as one in which the mean temperature between 6 a.m. and 6 p.m. was equal to or greater than 18°C (64°F), with at least six hours of sunshine and no precipitation. The minimum criteria defined by Crowe et al. for an operational golf day were: humidex values between 12°C and 33°C (55°F to 89°F); visibility greater than 3.2 kilometers (two miles); cloud cover less than eight-tenths; hourly wind speeds less than 32 kilometers per hour (less than 20 mph); and, no measurable precipitation.

There are a number of important limitations to this early study. First, the criteria to define a desirable golf day were based on expert opinion (from interviews with golf course managers and officials from the Toronto Department of Parks and Recreation), not observations of daily rounds played (i.e., actual golf participation during varied weather conditions). Second, the con-

[1]The report and survey used the term weather, yet they focus on the reasons for the change in annual rounds played from one year to another. Climate, specifically, inter-annual climate variability, is the more appropriate term.

cept of a desirable golf day is limited, both in space and time. Spatially, a desirable golf day is limited to the region in which it is defined; in the case of Crowe et al. (1977), it was the Great Lakes region of North America. For that reason, what is considered a desirable golf day in Toronto, may not be considered ideal in Miami, Phoenix, or Vancouver. Temporally, a desirable golf day could also vary throughout the year even in the same location. In temperate regions like Toronto for example, weather conditions that may result in golf courses operating at full capacity when they open in the spring (e.g., a sunny day with 15°C) may be perceived by golfers as less than ideal in July and August, resulting in the course operating at less than full capacity. Third, while the approach for defining a climatologically desirable or marginal golf day provides some insight into the length of the golf season, this approach does not provide insight into the number of rounds played, which is an important economic indicator for the golf industry.

In the first known analysis of the implications of climate change for the golf industry, Lamothe & Périard Consultants (1988) used Crowe et al.'s (1977) criteria for defining a climatologically desirable golf day to assess the impact of climate change on the length of the golf season in southern Quebec (Canada). Under a doubled atmospheric carbon-dioxide scenario (~2050s), they estimated the golf season in southern Quebec would be extended six weeks from its current 29-week average season.

More recently, Loomis and Crespi (1999) attempted to project golf participation in the United States under climate change. They established an equation relating the number of rounds played annually to two climate variables (temperature and precipitation), average income and the number of golf courses in each U.S. state. Although they do not describe how rounds played were converted into golf days, they projected that under the arbitrary climate change scenario they used (+2.5°C/4.5°F; +7% precipitation), the U.S. golf industry would benefit from a 14% increase in golf days in the 2050s.

This study is the second-known attempt to model the impact of climate change on the golf industry, but the methodology used also limited its contribution to understanding the potential impact of climate change on the golf industry. First, only one arbitrary climate change scenario was considered and it was applied to the entire country. As such, the study did not take into account climate change uncertainty by examining a range of future climates (as recommended by the Intergovernmental Panel on Climate Change) and ignored the regional differences of projected climate change in the United States. More importantly, the study did not distinguish local and state-level golf from out-of-state tourism-based participation (e.g., golf tourism to states like Florida and Arizona from regions where golf courses are closed in winter). The model therefore projected increased participation in northern states as temperature increased, but did not subtract the diminished flow of golf tourists to states that are currently golf destinations in the winter months.

The impact of weather and projected climate change on the golf sector are important issues that the golf industry has identified as requiring further analysis. The lack of research examining the impact of weather and climate on the golf industry was acknowledged by the World Golf Foundation (2001) in its *2001 20/20 Golf Industry Report.* The report recommended that more analysis of rounds played and weather [and climate] was needed. The lack of available golf participation data was identified by the World Golf Foundation as a critical limiting factor for this area of research; a important barrier encountered during this study. The need for research into the potential impacts of climate change on the golf sector has also been acknowledged by the European golf industry. Drawing on the input of over 250 stakeholders, including course mangers, union leaders and professional organizations, the Golf Course Advisory Panel at the Royal and Ancient Golf Course of St. Andrews (Scotland) identified climate change as one of six strategic issues facing the golf industry over the next twenty years (Royal and Ancient Golf Club of St. Andrews, 2000).

This case study is concerned with understanding the current influence of weather and climate on golf participation in order to examine the potential impact of climate change on the golf industry. It involves an empirical assessment of weather and golf participation in the Greater Toronto Area (GTA) of southern Ontario (Canada). The GTA was selected because it has one of the highest concentrations of golf courses in Canada, future golf course development has been identified as an important land use planning issue in the next 25 years (Regional Municipality of Halton, 2000), and weather and climate are limiting factors for the golf industry in the region. The two specific objectives of this study were to: (1) examine the impact of weather on golf participation and develop a model of weather and golf participation, and (2) use the model to assess how projected climatic changes could affect the future of the golf industry in the GTA and nearby regions with similar climates (i.e., the Great Lakes Region) through changes in the length of the golf season and the number of rounds played.

Methods

Study Area

According to a report on golf participation in Canada, the province of Ontario contained the largest proportion (38%) of the country's 4,895,000 golfers in 2002 (Royal Canadian Golf Association, 2002). It is estimated that 23.6 million rounds of golf were played across the province of Ontario in 2002 (Royal Canadian Golf Association, 2002). The GTA is considered one of Ontario's major golf destination areas (KPMG, 2002) and has one of the highest densities of golf courses in North America (Traber, 2004). Located in southern Ontario (approximately 43°43'N, 79°23'W), the GTA has a population of approximately five million people. In 2000, there were 176 golf courses (18-hole equivalents) operating in the GTA, with approximately two-thirds accessible to the public (classified as either public or semi-private) (Regional Municipality of Halton, 2000).

Through communications with golf course superintendents in the region it was determined that individual golf courses are impacted by and respond to weather and climate somewhat differently. Some courses that are owned and operated by local governments try to maximize their use by opening as early as possible in the spring and closing as late as possible in the fall, even if the quality of playing conditions is low during these periods. Conversely, most private or higher-quality public golf courses are more concerned about the quality of playing conditions and player satisfaction than maximizing rounds played, and therefore have a somewhat shorter season.

Considering these different weather and climate sensitivities, several (10) golf courses representative of mid- to high-quality courses in the study area were contacted to provide data for this study. Only one course was able to provide the necessary data (daily rounds played) for more than one complete golf season. Course superintendents at some golf courses expressed interest in the study, but were unable to release what was considered proprietary business information. Inconsistency in record keeping was another important barrier. Some golf courses recorded participation as the number of rounds paid for each day, but not necessarily played (i.e., purchases of multiple green fee packages or tournaments were recorded when they were paid for not when they were actually played). Technological limitations in course management software posed another barrier, as some golf courses could only provide monthly averages for rounds played or averages for specific days of the week (i.e., all Mondays, Saturdays or holidays).

The course used in this analysis is a private, regulation 18-hole course (par 72; maximum 7,043 yards) centrally located in the GTA that tends to operate at approximately 90% capacity during the peak season. Green fees average about US$75 per 18-hole game, which is in the low to mid-range of the green fees charged by other premium private courses in the study area (US$100-150). Numerous championship events, including the Ontario Open and a variety of LPGA Tour events, have been played at this course.

Data and Analysis

This study utilized daily recorded golf participation data (number of rounds played) from the selected golf course for the 2002 and 2003 golf seasons. Analysis of the influence of weather on golf participation was undertaken using station data from the nearest Meteorological Service of Canada weather station that contained daily observations for 2002 and 2003. Temperature, precipitation and wind speed data were obtained for the Toronto Lester B Pearson International Airport station, located approximately 30 kilometers (19 miles) from the golf course.

The climate change scenarios used in this study were developed from monthly global climate models (GCM) available from the Canadian Climate Impacts and Scenarios (CCIS) Project. The scenario data available from CCIS are constructed in accordance with the recommendations set out by the United Nations Intergovernmental Panel on Climate Change (IPCC) Task Group on Scenarios. Three future timeframes were examined, each of which were based on a 30-year period of climate data (i.e., the 2020s represent the period 2010-39; the 2050s represent 2040-69; and, the 2080s represent 2070-99). All scenarios represent climate changes with respect to the 30-year baseline climate (1961-90). The IPCC also recommends that at least two climate change scenarios be used in climate change impact assessment in order to capture some of the uncertainty in future climatic conditions. The two global climate models used in this study were the National Center for Atmospheric Research (NCAR) model and the Centre for Climate System Research (CCSR) model. The specific climate change scenarios used were the NCARPCM B21 (a low greenhouse gas emission future) and the CCSRNIES A11 (a high greenhouse gas emission future). These two scenarios were selected from 19 available scenarios because the NCARPCM B21 scenario projects the smallest increase in annual mean and summer maximum temperatures in southern Ontario, while the CCSRNIES A11 scenario projects the largest increase in both temperature variables.

A difficulty noted by the climate change impacts research community is that many impact assessments, including this study, require climate change information at finer temporal and spatial scales than are generally available from GCMs (Wilby, Charles, Zorita, Whetton, & Mearns, 2004). There are several methodological approaches to producing higher resolution climate change scenarios, including regional climate models (RCMs), statistical downscaling, spatial and temporal analogues, and simple application of "climate change factors" to a reference climate. As a report prepared for the IPCC notes (Wilby et al., 2004), all have strengths and weaknesses depending on the application. RCM scenarios were not available for this study because they have not been run with a sufficient range of climate change scenarios for the study area. Instead, this study makes use of two of the other approaches, using a weather generator for statistical downscaling and a spatial analogue to validate model results. For this study GCM scenarios were downscaled to the daily level at the Toronto climate station using the Long Ashton Research Station (LARS) stochastic weather generator (Semenov, Brooks, Barrows, & Richardson, 1998). Weather generators are inexpensive computational tools that replicate the statistical attributes of a local climate and can be used to produce site-specific, multiple-year climate change scenarios at the daily timescale (Semenov et al., 1998; Wilby et al., 2004). LARS was selected for this study because it has been found to simulate precipitation statistics in Canada better than other weather generators (Qian, Gameda, Hayhoe, de Jong, & Bootsam, 2004). The LARS weather generator was first parameterized to the Toronto climate station using baseline climate data (1961-90) and then monthly climate change vectors from the NCARPCM B21 and CCSRNIES A11 scenarios were applied for each future time period (2020s, 2050s, 2080s).

To assess future golf participation at the selected golf course in the GTA under a changed climate, regression analysis was first used to develop an empirical relationship between weather and current patterns of daily golf participation. The regression analysis was performed on a range of climate variables, but the selection was limited to those that could be generated for the climate change scenarios. The regression analysis was performed on daily rounds played of the 2002 and 2003 seasons using three weather variables (daily maximum and minimum temperature and daily precipitation) and one temporal variable (day of the week). The resulting regression model was first run with weather data from the Toronto climate station for the 1961-90 period to establish the 30-year climatological baseline, against which future climate change scenarios would be compared. This should not be construed as an attempt to model actual participation in any given year between 1961 and 1990. Indeed the course used in this study has not been in operation that long and many major factors affecting rounds played over that length of time (e.g., population growth, market competition) are not considered. Rather the purpose of running the model with the climate data from 1961-90 is to establish the number of rounds played in a climatologically average year during the baseline period and 30 years is the standard used by climatologists to establish climatic averages (or "normals"). The regression model was then run with both climate change scenarios (NCARPCM B21 and CCSRNIES A11) for the 2020s, 2050s and 2080s.

Results

Influence of Weather on Daily Golf Participation

Similar to most of Canada and the northern regions of the United States, there is a distinct seasonality to golf supply and participation in the GTA. Communications with several golf industry representatives indicated that golf courses in the region typically operate from early-to-mid April to mid-to-late November. The golf course analyzed in this study typified this seasonal pattern, opening on April 16 and 24 (Julian days 106 and 114), and closing on November 15 and 24 (Julian days 320 and 338) in 2002 and 2003, respectively. Snow cover remained for an additional week in 2003, contributing to the course's delayed opening that year.

Golf participation during the spring (April and May) and fall (September to November) months was found to be lower than during the summer peak months of June, July and August. In the first few weeks of the season, fewer than 100 rounds of golf were played per day on average, which is approximately 50% less than the summer peak (~180 to 200 rounds per day). In the last few weeks of the season, only 50 rounds of golf were played weekly (~25% of peak participation). The distinction between participation levels in the first and last few weeks of the season likely reflects pent-up desire to play golf in the spring after the winter off-season.

Golf participation was also found to vary throughout the week. As shown in Figure 1, more rounds were played on average on Saturdays and Sundays than any other day of the week. Tuesday was the least popular day of the week for playing golf in both seasons.

Analysis of weather data revealed that different characteristics of weather influence day-to-day golf participation at the study area. Figure 2 demonstrates the relationship between daily rounds played and daily minimum and

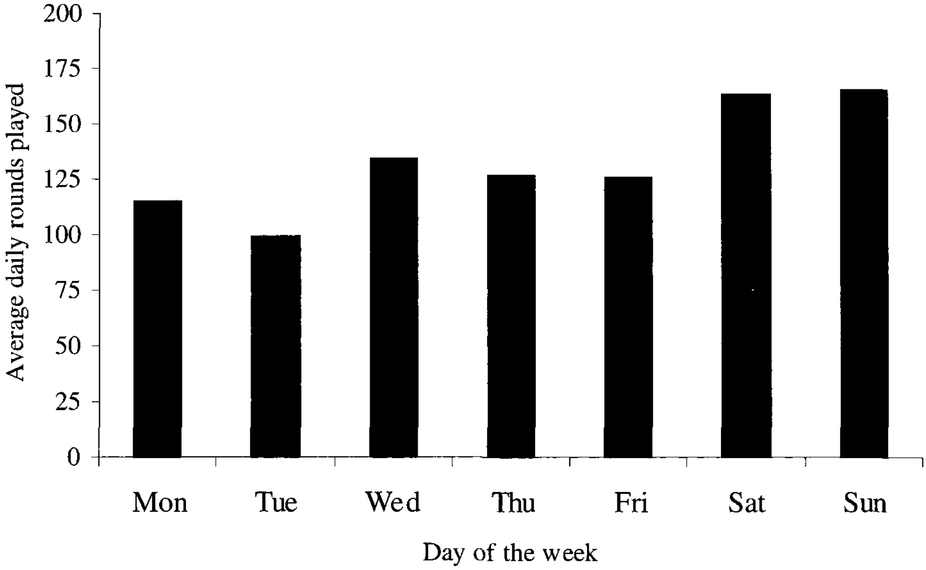

Figure 1. Impact of day of the week on mean daily rounds played

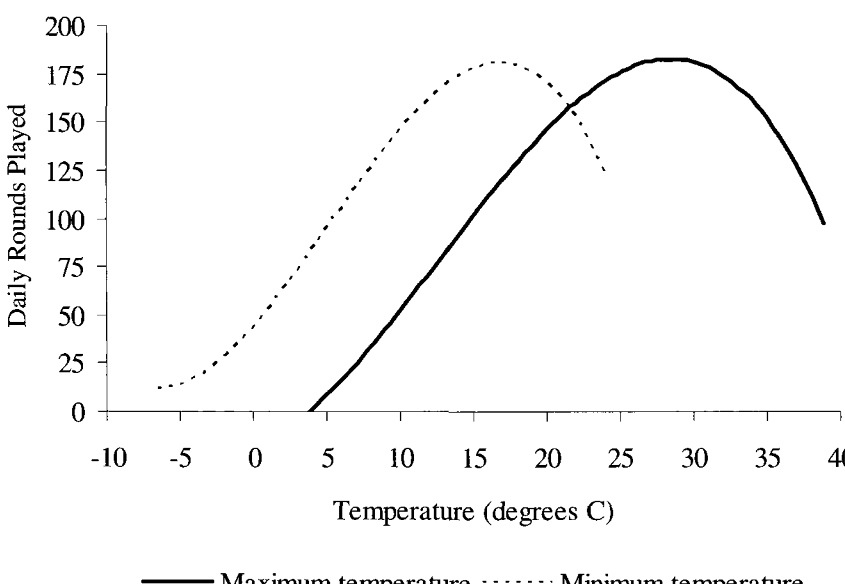

Figure 2. Regression relationship of maximum and minimum temperatures and daily rounds played

maximum temperatures. Daily rounds increased with temperature and began to stabilize and decline at a critical temperature. The critical minimum and maximum temperatures were 18°C (64°F) and 28°C (82°F), respectively. Conceptually, this relationship makes sense because at some critical maximum temperature the number of rounds played would be influenced by heat-related discomfort and eventually physiological heat-stress. The maximum and minimum temperatures that golfers find comfortable is likely to differ from region to region (e.g., Arizona versus Michigan), but no other studies are available to compare the results from the GTA against.

Precipitation also played a role in influencing daily golf participation. On average, 150 rounds of golf were played each day when no precipitation occurred. Daily golf participation declined 19.3% when 2.5 millimeters of rain occurred and 35.3% when between 2.5 and five millimeters occurred. Heavy precipitation was found to be a factor in most of the days when no rounds were played. Of the 16 days with zero rounds played, seven experienced more than 10 millimeters of precipitation that day, and another four had more than 20 millimeters the evening before.

Although the amount of precipitation plays an important role in influencing golf participation, when precipitation occurs also has effect on rounds played. Table 2 illustrates the average number of daily rounds played by a range of daily precipitation amounts and when the precipitation occurred (morning, afternoon or all day). Fewer rounds were generally played per day when precipitation only occurred in the morning, rather than the afternoon. When rain occurs in the morning hours it interrupts play, and golfers may decide not to play in the afternoon because they are uncertain about when the rain will end. If rain occurs in the afternoon, the morning rounds have already occurred and the number of lost rounds is reduced. Average daily rounds were typically at a minimum when precipitation lasted for the duration of the business day. On average, day-long precipitation reduced golf participation between 26% (to 111 rounds) and 87% (to 19 rounds).

Wind also influenced the number of rounds played each day. Rounds played were at a maximum when wind speeds were less than 20 kilometers per hour (13 mph) and participation declined as wind speeds increased.

TABLE 2

Impact of Precipitation Amount and Time of Day on Mean Daily Rounds Played

	Daily Precipitation				
Time of Day	0 mm	<2.5 mm	2.5 to 5 mm	5 to 10 mm	>10 mm
No rain	150				
Morning rain		104	92	76	48
Afternoon rain		137	122	151	136
All-day rain		111	19	62	42

Higher wind speeds were primarily associated with storm systems (e.g., thunderstorms).

The primary objective of this study was to explore the potential impact of climate change on annual golf participation. In order to assess the potential impact of climate change on golf participation, a stepwise multiple regression analysis that included three weather variables (maximum and minimum temperature, precipitation amount) and one temporal variable (day of the week) was completed. Based on the results presented in Figure 1, days of the week were classified as weekend, Tuesdays or other weekdays in the analysis. Although the timing of precipitation (morning, afternoon or all day) and wind speed were found to influence golf participation at the daily level, these variable were excluded from the regression analysis because they are not available as daily outputs in the current generation of climate change scenarios. Regression analysis resulted in a four-variable model ($r^2 = 0.60$), revealing that maximum temperature (t-statistic = 6.37), precipitation (t-statistic = −7.08), day of the week (t-statistic = 9.88) and minimum temperature (t-statistic = 2.0) were all predictors of daily rounds played throughout the year at the study area. The expression of the regression model in this study was:

$$\begin{aligned} \textit{Daily rounds played} = & -16.38 + 4.64\ (\textit{maximum daily temperature}) \\ & + 1.72\ (\textit{minimum temperature}) \\ & - 3.25\ (\textit{daily precipitation}) \\ & + 36.52\ (\textit{day of the week}) \end{aligned}$$

An important limitation of the multiple linear regression model is that is continues to project an increase in rounds played as the maximum temperature increases. To account for the affect of an upper temperature threshold on golf participation in the GTA (as seen in Figure 2), a high heat adjustment factor was added to the model. Heat alerts in the GTA are issued under the direction of the Toronto Heat Emergency Plan. Although many factors are evaluated, a base temperature of 32°C (90°F) is usually considered a reasonable proxy for a heat alert, as it could lead to physical discomfort and physiological heat-stress in vulnerable populations. Based on the observed relationship between declining participation and increasing maximum temperature in Figure 2, modeled and projected rounds played were reduced 6% for every 1°C (+1.8°F) increase over 32°C. Some climate adaptation by golfers in the GTA was assumed and no reduction in participation was applied between 28°C and 32°C (82°F and 90°F)

When the adjusted regression model was run with the climate data for the 30-year climatological baseline period, the average number of rounds played per year was 27,050. Discussions with a number of golf course superintendents in the GTA and a marketing analysis by Glenn Schnarr and Associates (1997) revealed that 30,000 rounds is a seasonal average for higher-quality 18-hole golf courses in the region. The difference between the industry estimate and the modeled average (~10%) was anticipated because the case study course does not operate at capacity during the peak season and was therefore deemed acceptable. An acknowledged limitation of the study is that other weather (timing of precipitation and wind speed) and business factors (e.g., tournaments or special events; business decision to open or close the course at the same time as competitors; not when climatically optimal) that can affect golf participation on a daily level could not be taken into account because they could not be modeled in the future climate change scenarios.

Impact of Climate Change on Golf Participation

The regression model developed in this study was run with the climate change scenarios to explore how golf participation in the study area could be affected by a warmer climate. A comparison of the projected changes in rounds played under the two climate change scenarios consistently indicated a trend toward higher golf participation, although there are some important differences in the magnitude and the timing of change among the two scenarios.

The results of the climate change impact assessment suggested that golf courses in the GTA that continued to operate only between mid-April and mid-November (~214 days), the current average operating season, would benefit under a warmer climate (Table 3). The average number of rounds played was projected to increase between 5.5% (NCARPCM B21) and 13.5% (CCSRNIES A11) by the 2020s. In the 2050s, the projected increase in

TABLE 3
Projected Golf Participation under Climate Change Scenarios (Annual Rounds)

	Modeled Average Rounds (1961-90)	2020s		2050s		2080s	
		Rounds	%Δ	Rounds	%Δ	Rounds	%Δ
Current Average Golf Season (214 days)	27,050						
		Scenarios for Current Average Operating Season (214 days)					
NCARPCM B21		28,551	+5.5%	29,135	+7.7%	29,765	+10.0%
CCSRNIES A11		30,699	+13.5%	33,453	+23.7%	34,730	+28.4%
		Scenarios for 'Climate Adapted' Operating Season (maximum 365 days)					
NCARPCM B21		33,384	+23.0%	34,257	+26.6%	35,570	+31.5%
CCSRNIES A11		37,084	+37.1%	43,417	+60.5%	46,720	+72.7%

rounds played is even more pronounced, ranging from 7.7% (NCARPCM B21) to 23.7% (CCSRNIES A11). The additional warming projected for the 2080s contributed to an increase in rounds played of between 10.0% (NCARPCM B21) and 28.4% (CCSRNIES A11). With the modeled season length restricted to the current average opening and closing periods (Julian day 106 and 318, respectively), the increase in rounds played occurs largely because of more conducive weather conditions during the months of April to May and October to November (Figures 3 and 4).

It was assumed that golf managers in the GTA would adapt to the new opportunities provided by a changed climate in the region. Consequently, the model was also run with the assumption that golf courses would open and close when participation reached levels typical of current opening and closing days (approximately 75 and 50 rounds per day, respectively). There is little noticeable extension in the average golf season under the NCARPCM B21 scenarios. Under the much warmer CCSRNIES A11 scenario, however, the climate change adapted golf season is projected to be 51 days (~seven weeks) longer in the 2020s and 86 days (~12 weeks) longer in the 2050s. In the 2080s, golf is projected to have a potential season length of 323 days (Julian day 42 to 365), approximately 16 weeks longer than at present. Although the potential for a year-round golf season exists in the study area under the warmest scenario for the 2080s, it would remain intermittent at best as daily mean temperatures during the winter months of December through to February are projected to be remain relatively cool (~2.5°C; 36°F) with extended periods of frost and snow cover in most years.

In order to provide some validation of the climate change assessment for the study area, a spatial analogue approach was employed. A comparison

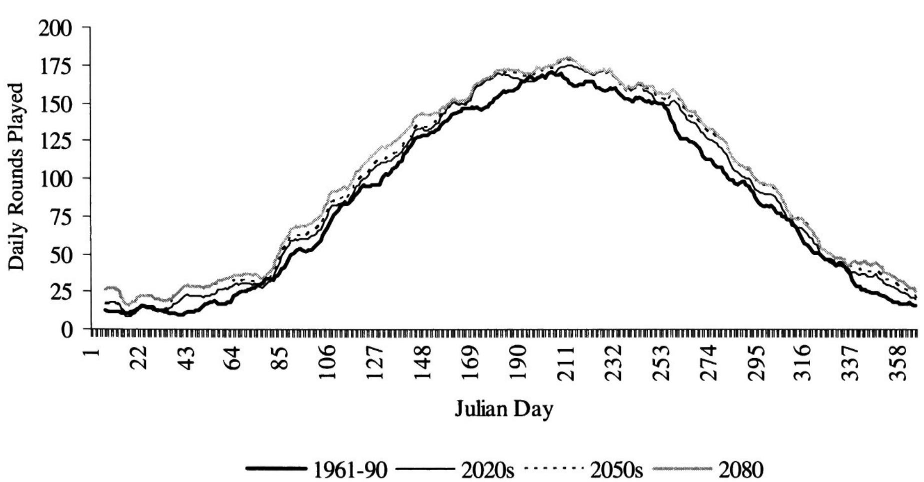

Figure 3. Projected daily rounds played (7-day running average) under the NCARPCM B21 climate change scenario

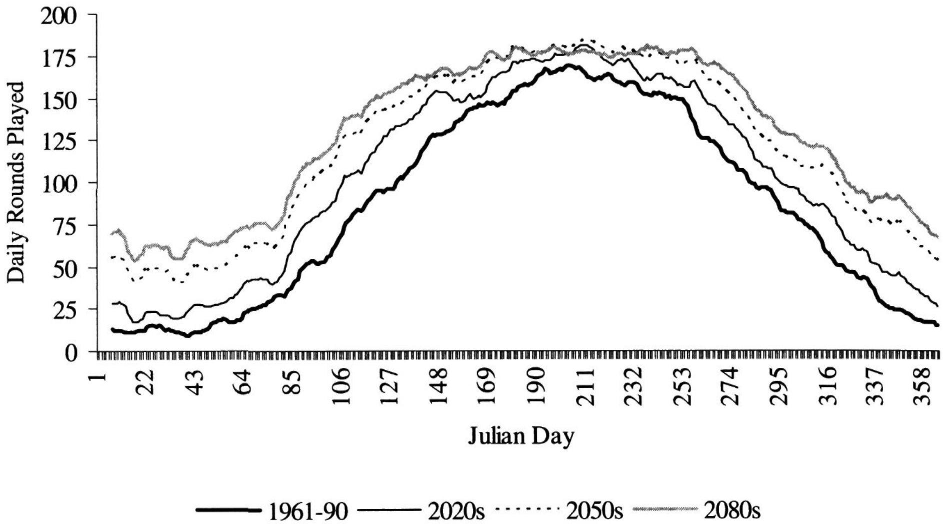

Figure 4. Projected daily rounds played (7-day running average) under the CCSRNIES A11 climate change scenario

of the projected climate for the GTA under the warmest climate change scenario for the 2080s revealed it would have a climate similar to Columbus, Ohio (40°0′ N, 83°1′ W) today. Examination of opening and closing dates for 28 courses in the Greater Columbus Area revealed that a large proportion (60%) are currently open year round, but rounds played are intermittent during the months of December to February because temperatures frequently fall below 0°C (32°F) during the day. Courses that were not open year round generally had golf seasons ranging from 275 days (~Julian day 60 to 335) to 333 days (~Julian day 32 to 365). When the season lengths of all 28 courses were considered, the average golf season in Columbus was found to be 333 days. Based on the Columbus results, it is suggested that the modeled 323-day average golf season (~3% difference from the Columbus area average) for the GTA is a reasonable assessment of the future length of the golf season in the study area under the warmest scenario for the 2080s.

When golf rounds played were assessed, the projected increase was much larger with a climate change adapted golf operating season, especially under the warmer CCSRNIES A11 scenario (Table 3). With a climate adapted operating season, the increase in the average number of rounds played per season is projected to range from 23.0% (NCARPCM B21) to 37.1% (CCSRNIES A11) in the 2020s and 26.6% (NCARPCM B21) to 60.5% (CCSRNIES A11) in the 2050s. In the 2080s, an 18-hole golf course in the GTA could experience between 31.5% (~8,500 rounds) and 72.7% (~19,700 rounds) more rounds annually. Examination of participation at 10 Columbus, Ohio area golf courses revealed an average of 47,600 rounds at courses that remain open year round. Again, it is suggested that the modeled 46,720 annual rounds in this study (~2% difference from the Columbus area average) is a reasonable projection for the GTA golf course in the warmest scenario for the 2080s.

What are the implications of climate change for the golf industry in the GTA? If the results from the case study are extrapolated, the 176 golf courses (18-hole equivalents in 2000) in the GTA have a potential market of 4.8 million rounds in a climatically average season today. Under a conservative climate change scenario where there is no change in the current length of the golf season (~214 days) to take advantage of a warmer climate, annual rounds in the GTA could increase to between 5.0 million (NCARPCM B21) and 5.4 million (CCSRNIES A11) as early as the 2020s. If there is optimal adaptation to climate change (i.e., all courses maximize operating seasons to take advantage of altered climatic conditions), then the number of rounds played in the GTA could increase to between 5.9 million (NCARPCM B21) and 6.5 million (CCSRNIES A11) in the 2020s and increase to as many as 8.2 million rounds in the 2080s under the warmer CCSRNIES A11 scenario. If population growth in the GTA was also factored in, the projections of annual rounds played would be even higher.

Discussion

This study examined the influence of daily weather on golf participation and developed a model to explore the potential impact of climate change on the golf industry in the GTA (southern Ontario, Canada). Although only two years of observed data were available, the results clearly illustrated the disparate impacts of weather (temperature, precipitation and wind) on daily golf participation. The climate change impact assessment indicated that golf participation would increase in the study area even under the most conservative climate change scenario. The model projected increases in annual rounds played in the range of 5.5% to 13.5% in the 2020s and 7.7% to 23.7% in the 2050s even if golf courses did not adapt their operating seasons to new climatic conditions. Golf courses with climate change adapted operating seasons were projected to benefit further, with increases in annual rounds played of 23.0% to 37.1% in the 2020s and 26.6% to 60.5% in the 2050s. Under the warmer CCSRNIES A11 scenario, the average golf season in the GTA could be extended up to 16 weeks in the 2080s. This would give the GTA a golf season much like that of Columbus, Ohio, which currently has a climate very similar to that projected for the GTA under the 2080s CCSRNIES A11 scenario.

Although weather and climate are recognized as important factors in the success of the golf sector, very little research has explored the current relationship between them and the implications for the future under a changed climate. This case study contributes to the advancement of our understanding of the influence of weather on golf participation and the potential impact of climate change, but it also has limitations. Despite repeated efforts to obtain longer time series from multiple courses, this study was based on only two years of daily golf participation data from a single golf course. A longer observed record of data would have provided an opportunity to examine the impact of climate extremes (e.g., a very warm spring, very hot summer) on golf participation. These extreme seasons could be used as analogues for the future as climate changes and would provide insight into behavioral change by golfers and the golf course managers in the study area. While the spatial analogue (Columbus, Ohio) provides some validation of the model, data from other golf courses in the study area are needed to better determine how representative the findings are for the golf industry in the region.

Communications with golf industry stakeholders suggest there is a high likelihood that the results are generally applicable to similar quality courses in other regions of southern Ontario and southern Quebec. Canada is a large and climatically diverse country and the results are not considered generalizable to other regions where other climatological variables (e.g., fog or relative humidity) could have an important influence on golf participation.

Golf participation was the focus of this study, but participation is only one aspect of the golf industry that could be impacted by climate change. To assess the full potential impact of climate change on the golf industry the implications for a full range of golf course operations also need to be examined. The warmer climate projected by the CCSRNIES A11 scenario would lead to greater demand for turf grass irrigation in the study area. A 1998 survey of Canadian golf courses found water availability or cost was currently or was soon expected to be a problem for 22% of courses (Royal Canadian Golf Association, 1999b). With increased competition for water in the future, climate change is anticipated to exacerbate the challenge of water supply for the industry. This is particularly the case in some of the top golf destinations in the United States that are projected to have acute water supply challenges in the coming decades even if climate change does not occur. Another important issue for golf operations is the potential impact of climate change on grass maintenance issues, such as turf grass selection, turf diseases and insect pests. Pests that currently have only one life cycle in southern Ontario could adapt to new climate regimes and have two life cycles (Vittum, 2003). Perhaps more importantly, there is the potential for turf grass diseases and pests currently limited to more southerly latitudes to expand into southern Ontario and require management interventions in the future. Future analysis of these operational issues is essential to provide insight into the potential ability of golf courses to take advantage of the opportunities projected climate change would bring.

The primary objective of this study was to explore if and when (2020s, 2050s and 2080s) projected climate change would have a meaningful impact on the golf industry in the GTA. The potential impact of climate change was assessed exclusively, without consideration of other major factors that would affect golf participation in the study area decades into the future (e.g., population growth, demographic change [aging population, increased ethnic diversity], the supply of golf courses, the costs of participation [equipment, green fees, time]). Now that it has been established that climate change is very relevant to the future of the golf industry in the study area, future research will need to assess how climate change may interact with some of the aforementioned other factors.

This case study was the first assessment of climate change and the golf industry of its kind. It is hoped that this study and the methods developed will encourage further research into the role of weather in golf participation and the implications of climate change for the golf industry. The very limited research on the impacts of climate change for the recreation and tourism sector in North America, relative to other economic sectors, is not justified considering the current and growing significance of this sector to the economies of many communities in Canada and the United States.

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