Climate and Visitation to Utah's "Mighty 5" National Parks

Abstract

The relationship between climate and visitation to managed natural areas has been analyzed at a variety of different spatial scales. We expand upon our existing knowledge on this topic by: 1) determining how a wide range of climate variables affect visitation across a regional tourism system; and 2) identifying which variables affect visitation system-wide and which variables only affect visitation at specific parks. Our analysis focuses on five national parks located in southern Utah (U.S.A.) commonly referred to as "the Mighty 5." We found monthly average daily maximum temperatures were the best predictor of system-wide visitation, suggesting average daily maximum temperatures play a more direct role in tourists' travel decisions relative to other climate variables, including other derivations of temperature. We also found declines in monthly park visitation for three parks (Arches, Canyonlands, and Capitol Reef) once average daily maximum temperatures exceed 25 C. For Bryce Canyon and Zion however, monthly visitation continued to increase well above this threshold. The geophysical characteristics of these parks appear to mediate the relationship between average daily maximum temperature and visitation. The commonly-found "inverted U-shape" relationship between temperature and visitation should not be seen as a universal maxim. We also found precipitation to be a poor predictor of system-wide visitation, but a significant factor shaping the travel decisions of visitors to Bryce Canyon, the only park to offer snow-based outdoor recreation opportunities. Future research should not disregard the possibility of precipitation being a significant factor shaping visitors' travel decisions. By conducting our analyses at two distinct scales, we have found there is a difference between the individual climate variables that are regionally-significant drivers of visitation and those that are locally-significant drivers of visitation. Scale matters in analyses of the relationship between climate and visitation.

Keywords: Climate change, nature-based tourism, outdoor recreation, Utah, weather

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Introduction

Visitation to managed natural areas is highly dependent upon climate and weather. Many tourists select their destinations based upon expected climatic conditions (Hamilton & Lau, 2006) while many regional tourists and local visitors plan their trips to areas where the near-term weather forecasts project desirable conditions (Patrolia, Thompson, Dalton, & Hoagland, 2017; Rutty & Andrey, 2014). Often, regional and local tourists adjust their trip timing and alter their length of stay or the outdoor recreation activities they participate in, based on the weather (e.g., Becken & Wilson, 2013). The relationship between climate, weather, and visitation to managed natural areas has been analyzed at a variety of different spatial scales ranging from specific national parks (e.g., Richardson & Loomis, 2004; Scott, Jones, & Konopek, 2007), to regional tourism systems (e.g., Coombes, Jones, & Sutherland, 2009; Smith et al., 2016), to national (e.g., Fisichelli, Schuurman, Monahan, & Ziesler, 2015; Liu, 2016) and international (e.g., Barrios & Ibañez, 2015; Lise & Tol, 2002) networks of tourism destinations. These studies most often correlate past visitation rates with a select set of climate variables, among which temperature is used most often (Gössling & Hall, 2006). Here, we expand upon our existing knowledge about how climate and weather affect visitation to managed natural areas by analyzing historical shifts in visitation attributable to a broad set of climate variables across a regional tourism system[1].

Our objectives are twofold: First, to determine how a broad set of climate variables affect visitation to managed natural areas across a tourism system. Analyses of regional, national, and global tourism systems often identify a single climate variable (e.g., average daily mean temperature) that is significantly related to visitation to managed natural areas. Often these studies lack destination-specific data that can be utilized to determine if a wider spectrum of climatic variables (e.g., precipitation, cloud cover, etc.) are also related to visitation to managed natural areas. Exploring how a broad set of climate variables affect visitation across a regional tourism system will improve our understanding of which climate variables are most predictive of visitation. Our second objective is to identify which climate variables affect visitation across an entire tourism system and which climate variables only affect visitation at specific destinations. Many analyses of the relationship between climate and visitation ignore the issue of spatial scale, assuming globally-relevant climatic predictors of visitation affect all tourism destinations the same. This may not always be the case; some climate variables that are poor predictors of

[1] We are working from the definition of a tourism system as the combination of tourist generating regions, the tourist destination region, and the transit region. Our study is focused specifically on the tourist destination region, defined as the "locations which attract tourists to stay temporarily, and in particular those features which inherently contribute to that attraction" (Leiper, 1979, p. 397)

visitation across an entire system may be highly influential at specific destinations. Similarly, certain climatic conditions that affect visitation system-wide may have only a marginal or negligible effect on visitation at the local level. Scale matters in analyses of climate and visitation to managed natural areas. By identifying which climate variables affect visitation across an entire tourism system and which climate variables only affect visitation at specific destinations, our analyses can illustrate this point.

Related Literature

Climate Change and Tourism

A changing climate has the potential to considerably alter visitation to managed natural areas since outdoor recreationists and tourists are highly sensitive to climate and weather. For example, warming temperatures are likely to decrease the number of days with snow in many locations and thus displace some skiers (e.g., Dawson, Scott, & Havitz, 2013; Rutty et al., 2015; Scott, Dawson, & Jones, 2008). Past research has shown a direct correlation between weather conditions and the closure of New England ski areas (Beaudin & Huang, 2014), illustrating how climate change can alter the economies of tourism destinations. Although there is more research on the impacts of climate and weather on winter outdoor recreation, changes in summer weather have also been shown to influence tourists and thus have an effect on visitation and spending (Denstadli, Jacobsen, & Lohmann, 2011; Falk, 2015).

Previous research has investigated the potential impact of climate change on future national park visitation (e.g., Fisichelli et al., 2015; Liu, 2016; Scott et al., 2007). Scott and his colleagues (2007) modeled future visitation to Waterton Lakes National Park, Canada, by comparing past monthly visitation data to monthly temperature and precipitation. Similarly, Liu (2016) used temperature and precipitation to model visitation to Taiwan's national parks under climate change, finding precipitation was a stronger predictor of visitation. Relatedly, Richardson and Loomis (2004) modeled future visitation to Rocky Mountain National Park (U.S.A.), using minimum and maximum temperature, as well as precipitation and snow depth, as predictors of visitation.

Additionally, a previous study investigated the potential effect of climate change on future visitation at all U.S. National Park Service units (Fisichelli et al., 2015). Fisichelli and his colleagues used historical data on visitation and monthly average daily mean temperatures to predict visitation in the future. Results showed that warming temperatures were expected to increase winter visitation for all five national parks in Utah. However, there were differences in projected visitation under warming for the summer months; summer visitation for Zion and Bryce Canyon is expected to stay fairly constant under warming scenarios, while visitation for Arches, Canyonlands, and Capitol Reef is expected to decrease in the summer months (Fisichelli

& Ziesler, 2015a, 2015b, 2015c, 2015d, 2015e). These projections only considered monthly average daily mean temperatures as a driving force affecting visitation. We aim to further explore the differing impact of climate on Utah's national parks by investigating how a broad set of variables, including monthly average daily mean temperatures, influence visitation.

Investigating the impact of climate and weather on tourism flows is essential to understanding shifting patterns of visitation under climate change. Tourists can adapt to changing conditions either spatially (changing destinations), temporally (changing trip timing), or behaviorally (changing recreational activities) (Dawson et al., 2013). All of these adaptations impact the management of protected areas as well as the surrounding businesses and communities.

Climate and Weather Sensitivities for Tourism

Four climate and weather variables are commonly studied in tourism research: temperature (minimum, maximum, and/or mean), precipitation, wind, and sunshine (e.g., Hewer, Scott, & Gough, 2015; Scott, Gössling, & Freitas, 2008; Steiger, Abegg, & Jänicke, 2016). Tourists' perceptions of the importance of these variables depends on the destination's location and the geophysical characteristics of its landscape (Rutty & Scott, 2010; Scott, Gössling, et al., 2008). Surveys of tourists suggest that beach tourists tend to rate sunshine and precipitation as the highest importance (Moreno & Amelung, 2009; Scott, Gössling, et al., 2008), while mountain tourists perceive precipitation to be most influential (Scott, Gössling, et al., 2008; Steiger et al., 2016), while urban tourists are most sensitive to temperature (Scott, Gössling, et al., 2008). Additionally, perceptions of acceptable conditions tend to vary by individual based on their home location, their expectations and experiences of the destination's climate, and their planned recreational activities (Gössling, Abegg, & Steiger, 2016; Rutty & Scott, 2016; Scott, Gössling, et al., 2008). This has led research in dissimilar geographies to reach different conclusions about the impact of climate and weather on tourists. Because surveying visitors is time-intensive and costly, requiring field crews to be on-site at a destination for prolonged periods of time, these types of studies often are conducted on smaller, localized scales.

Research at coarser spatial resolutions often use historical climatic conditions and visitation data to investigate revealed preferences for specific climatic conditions (e.g., Fisichelli et al., 2015; Hewer, Scott, & Fenech, 2016; Jones & Scott, 2006; Loomis & Richardson, 2006; Scott et al., 2007). However, there is little consistency in which climate variables should be included in regional, national, or global modeling efforts. Some studies have focused on only temperature as the sole predictor of visitation, as temperature tends to be correlated with other climate variables and often is the strongest predictor (Bigano, Hamilton, Maddison, & Tol, 2006; Rosselló-Nadal, 2014). However, other studies have shown that additional climate and weather variables are often significant predictors as well (Falk, 2014; Rosselló-Nadal, Riera-Font, & Cárdenas, 2011; Scott & Jones, 2007), and sometimes even more influential than temperature (Yu, Schwartz, & Walsh, 2009). For example, Falk (2014) found that sunshine and temperature both had a positive effect on overnight stays in Austria, while precipitation had a negative effect. Similarly, Yu et al. (2009) found that storms and rain are the most important factors impacting visitors in King Salmon (Alaska, U.S.A.) and Orlando (Florida, U.S.A.) during the summer. In a different study however, Becken (2013) found that weather did not impact visitation to Westland, New Zealand, across years, although weather did drive tourism seasonality within each year. These differing conclusions suggest that geography and spatial scale may play a substantial role in modeling the impact of climate and weather on tourism.

The effect of climate and weather on tourism has also been studied using climate indices, such as the tourism climatic index (e.g., Amelung & Nicholls, 2014; Amelung & Viner, 2006; Mieczkowski, 1985; Perch-Nielsen, Amelung, & Knutti, 2010; D. Scott, McBoyle, & Schwartzentruber, 2004). Tourism indices incorporate multiple climate and weather variables, but often assume the variables specified in the model have the same importance for every location and tourist type (Scott, Rutty, Amelung, & Tang, 2016). Additionally, the indices do not account for the local topography of an area. Some destinations may contain more microclimates within one area, which allow for tourists to somewhat alter the weather they experience (Rutty & Scott, 2014). For example, people in mountainous destinations could travel to higher elevations for cooler weather, or tourists in areas with canyons could seek less sunshine and cooler temperatures by recreating in canyon bottoms. Some destinations have more microclimates than others, which increases the adaptive capacity of tourists visiting those destinations.

While a variety of different climate and weather variables have been used in previous research, the effects of those variables have been inconsistent, appearing to be dependent on the geographic location, dominant activity type at the destination, and spatial scale of analysis. Studies at the national or international scale tend to only focus on the importance of temperature, while more site-specific variables are often disregarded (e.g., Berrittella, Bigano, Roson, & Tol, 2006; Serquet & Rebetez, 2011). However, studies at smaller spatial scales often find other variables, besides temperature, to be meaningful predictors of visitation to managed natural areas (e.g., Førland et al., 2013; Köberl, Prettenthaler, & Bird, 2016; Yu et al., 2009). Because of these inconsistencies, we investigate the impact of numerous climate variables at two spatial scales.

Methods

The Mighty 5

Our analysis focuses on a regional network of national parks located in southern Utah (Figure 1). The parks – consisting of Arches, Bryce Canyon, Canyonlands, Capitol Reef, and Zion – are commonly referred to at "the Mighty 5." The moniker is the product of an ad campaign launched by the Utah Office of Tourism in 2013. The campaign sought to market the parks as a regional tourism destination. Along with the ad campaign, the Utah Office of Tourism released three to ten day itineraries that would guide visitors from either the Salt Lake or Las Vegas international airports to two or all five national parks, depending on the length of the trip (Utah Office of Tourism, N. D.). The success of Mighty 5 was immediately apparent. Park visitation prior to 2000 had been steadily increasing. In the year the campaign launched, all five of Utah's national parks received a total of 6.3 million visitors (National Park Service, 2017). After the ad campaign, visitation abruptly rose by 60.3% over three years, resulting in 10.1 million national park visitors in 2016 (National Park Service, 2017).

[INSERT FIGURE 1 HERE]

To the tourism industry and the state, the increase in visitation and visitor spending was welcome; however, the millions of additional people visiting the national parks each year has put a great deal of strain on National Park Service managers. The National Park Service's mission is twofold: protect the land and serve the people. With millions of additional people coming to Utah's national parks each year, park managers were, and are, having a difficult time protecting park resources and providing quality national park experiences.

Characteristics of Each National Park

Average monthly climatic conditions for each of the five park units is shown in Supplemental Figure 1. Importantly, three of the study parks are located within the Colorado Plateau (Arches, Canyonlands, and Capitol Reef) while the other two parks (Bryce Canyon and Zion) are located in the southernmost extent of the southern Wasatch mountains. The differences in ecoregions affects the types of recreational opportunities that are offered within the parks, with Bryce Canyon and Zion offering more trails in canyons and with vegetative cover. The parks in the Colorado Plateau tend to be more exposed, with few opportunities for escaping daily high summer temperatures that can often exceed 30 C.

Arches is the most eastern park in the state of Utah, and sits just northeast of Moab. Being part of the Colorado Plateau, the climate can be characterized as "high desert", which means it is arid, with hot summers and cold winters, and large daily temperature fluctuations that often span a range of 21 C. The park is characterized by protruding sandstone formations amongst a relatively flat desert floor covered by low-growing vegetation. The difference between the lowest and highest elevations in the park (i.e., vertical relief) is 516 m.

Bryce Canyon is located in southcentral Utah. It has the highest elevation of Utah's national parks (~2,778 m), which means it has lower temperatures, more vegetation, and more snow accumulation. Bryce Canyon is the only national park within Utah to offer snow-based recreational activities including cross-country skiing and snowshoeing. The park often receives over 45 mm of precipitation per month in the fall and and averages 30 mm of precipitation in the winter months, most of which falls as snow. Much of Bryce Canyon's upper elevations are covered by conifer forests, but as areas of the park descend into lower elevations the vegetation changes into ponderosa pine forest, and then further down it transitions into pinyon and juniper. The vertical relief of the park is 780 m. Across this gradient are hundreds of "hoodoos", unique steep-sided geological formations that rise from the valley floor.

Canyonlands is located just west of Moab, and is the largest of the five national parks. Like Arches, Canyonlands is in the heart of the Colorado Plateau, giving it many of the same "high desert" climatic and vegetative characteristics. Summer temperatures in the park often exceed 30 C. However, just as its name implies, the topography is much more extreme. Total vertical relief of the park is 1,030 m. The two main canyons in the park were created by the Green and Colorado rivers, which enter the northern end of the park, converge in the middle, and flow out of the southern end. Many visitors are attracted to Canyonlands due to the kayaking and rafting opportunities offered on both the Green and Colorado river.

Capitol Reef is located in south-central Utah and is characterized by its brightly colored canyons, cliffs, monoliths, and buttes. Maximum daily temperatures often exceed 30 C in the summer months. The park is centrally located in the Colorado Plateau and its landscape is high arid desert with several slot canyons cut in by the Fremont River. Total vertical relief in the park is 1,549 m. The park is filled with several different types of sandstone that comprise hundreds of domes, towers, monuments, bluffs, and spires across the landscape.

Zion is the most southwestern park in Utah and is located at the junction of the Colorado Plateau, the Great Basin, and the Mojave Desert. The landscape is varied, with the lowest point of elevation at 1,110 meters and the highest at 2,660 meters. The largest feature in the park is Zion Canyon, which is fifteen miles long, and up to half a mile deep. The park's canyons, along with dense vegetative cover in their bottoms, shade and cool many of the most heavily used trails within the park. Shade and cooler temperatures are often a relief, as daily maximum temperatures can often exceed 33 C in the summer months. Amongst our study parks, Zion offers the largest vertical relief, spanning 1,550 m.

All of the study parks have visitor centers which do offer some respite from extreme or unanticipated weather conditions. Given this, the indoor amenities of individual parks is not believed to affect the relationship between specific climate variables and visitation.

Data

Monthly recreation visits. We obtained the total number of monthly recreation visits for the five study parks between January 1979 and December 2014 from the National Park Service's Integrated Resource Management Applications Portal (National Park Service, 2017). A recreation visit is a unique entrance into the park for the purpose of participating in outdoor recreation. The method of counting recreation visits for each park unit are described in Supplemental Table 1.

Monthly visitation by park, averaged between 1979 and 2014, are shown in Figure 2. Because visitation rates are notably different across the five study parks, we converted the raw monthly visitation data to each month's proportion of the yearly visitation total. This monthly proportion served as the dependent variable in the time-series regression models described below. The method of using each month's proportion of the yearly visitation total ensures parks with larger total visitation amounts do not bias estimated coefficients; the method is also consistent with previous research (Fisichelli et al., 2015).

[INSERT FIGURE 2 HERE]

Local climate data. We obtained gridded climate data from the Climatic Research Unit (CRU) time-series version 3.23 (Harris, Jones, Osborn, & Lister, 2014). These data estimate a suite of climate variables at 0.5 decimal degree increments across the globe for every month between January 1901 to December 2014. Given monthly recreation visits for each of the five study parks has only been recorded since January 1979, we only use climate data spanning the same timeframe (January 1979 through December 2014). The suite of climate variables estimated in the CRU time-series data are: monthly average daily mean temperature; monthly average daily minimum temperature; monthly average daily maximum temperature, diurnal temperature range, potential evapotranspiration, precipitation, wet day frequency, frost day frequency, percentage cloud cover; and vapor pressure. Derivations of these data have been used in previous research to examine the climate change exposure of U.S. National Parks (Monahan & Fisichelli, 2014). Additionally, the monthly mean air temperature variable has been correlated with monthly visitation rates to park units across the U.S. (Fisichelli et al., 2015). Details on each of these climate variables are provided in Table 1.

[INSERT TABLE 1 HERE]

For each study park, we obtained the historical climate data for each grid cell within a 30km buffer of the park boundary. The use of a 30km buffer is consistent with previous research (Fisichelli et al., 2015; Monahan & Fisichelli, 2014) and with the NPSs' standards (NPS Natural Resource Inventory and Monitoring Division, 2016). The buffer mitigates against measurement biased introduced from the coarse nature of the climate data and ensures ecological processes beyond a park's boundary, which might also affect visitation, are also captured (Hansen et al., 2011). For each month between January 1979 and December 2014, we averaged the climate variables across each park unit's relevant grid cells to create park-specific average climate measures. Because the parks vary in size and shape, the number of relevant grid cells varied by park (Arches = 2, Bryce Canyon and Zion = 4, Canyonlands = 9, Capitol Reef = 12). The maximum deviations between the averaged values and the observed values for any specific grid cell were: monthly average daily mean temperature = 7.2 C; monthly average daily minimum temperature = 8.1 C; monthly average daily maximum temperature = 6.6 C; diurnal temperature range = 5.6 C, potential evapotranspiration = 1.6 mm; precipitation = 69.4 mm, wet day frequency = 3.6 days; frost day frequency = 14.9 days; percentage cloud cover = 13.2; and vapor pressure = 3.8 hPa.

U.S. Dollar Index. International visitation to the U.S. is driven, to a certain extent, by the value of the U.S. dollar (Anastasopoulos, 1989). Anecdotal evidence suggest national park visitation within the country is also related to the value of the dollar (U.S. Travel Association, 2016). Given this, we also included the U.S. Dollar Index as an independent variable in our panel time series models. The U.S. Dollar Index is a measure of the value of the dollar relative to the value of currencies from a set of the country's most significant trading partners. We downloaded U.S. Dollar Index data from January 1, 1979 to December 31, 2014 from the Federal Reserve (www.federalreserve.gov). We averaged the daily data across the month for inclusion in the regression models described below.

Analysis

Previous climate/visitation research has used average daily mean temperature as a predictor of park visitation (Rosselló-Nadal, 2014). Analysis using average daily mean temperature as the sole predictor of park visitation will not be able to capture shifts in visitation driven by other climate variables (e.g., consistent increases/decreases in precipitation levels or increases in maximum mean air temperature that outpaces increases in mean air temperature). Given this, our analysis included all ten climate variables within the CRU time-series data set. We use the raw climate data, as opposed to using a composed climate index (e.g., Mieczkowski, 1985). Due to high correlations between several of the climate variables, each is analyzed in isolation as a distinct predictor of shifts in historical visitation.

We constructed and estimated panel[2] time-series regression models using the monthly climate and visitation data. Macro panel data such as ours often include some form of cross-sectional dependence (CSD), which is simply a lack of independence across units within the sample (Kapetanios, Pesaran, & Yamagata, 2011). More explicitly, CSD results is a correlation structure in the error term across units within the sample attributable to unobservable common factors affecting the relationship between the regressors and the dependent variable. In the case of national park visitation, for example, an unobservable common factor affecting the relationship between climatic conditions and park visitation would be the demographic profile of the domestic visitors. As the U.S. population ages, it is not unreasonable to assume that the relationship between climatic conditions and park visitation may be exaggerated. Lise and Tol (2002) demonstrated how older tourists have different climate preferences relative to younger individuals). Unobservable common factors could include any omitted variable (Banerjee & Carrion-i-Silvestre, 2017). Methods for dealing with CSD have evolved from incorporating time

[2] Panel data describe a sample of units (in this case, national parks) which are repeatedly measured over time (in this case, each month from January 1979 to December 2014). When panel data describe a relatively few number of units over a long time period (small *N*, large *t*) they are described as a macro panel (Hsiao, 2014).

dummies into the regression model to estimating principal components of the residual error terms (Coakley, Fuertes, & Smith, 2002). More recent econometric work by Pesaran (2006) has shown how including cross-section averages in each *t* of time for both independent and dependent variables can control for unobservable common factors; this is the approach we use in our analysis. Burdisso and Sangiácomo (2016) provide a thorough review of the evolution of panel time series models, with specific attention paid to how to best deal with CSD.

Our model is specified as:

$$y_{it} = \beta_i' z_t + \beta_i' x_{it} + \beta_i' d_t + \beta_i' \bar{y}_t + \beta_i' \bar{x}_t + \epsilon_{it}$$

where y_{it} is each months (*t*) proportion of its year's annual visitation total for each park (*i*); z_t is a trend variable, which does not differ over parks; x_{it} is the climate variable specific to each park and month; d_t is the monthly average for the U.S. dollar index; $\bar{y}_t$ is the average of the proportional visitation (*y*) across all park units; $\bar{x}_t$ is the average of the climate variables across the park units for each month; and ϵ_{it} is the remaining unobservable disturbance. All estimated coefficients are represented as β'. Both $\bar{y}_t$ and $\bar{x}_t$ serve as proxy measures for unobserved common factors that may affect park visitation. Estimation of the panel time series models was completed using the xtcce command in Stata 14.0.

Results

Descriptive Statistics

Average monthly values for each of the ten climate variables and the visitation variable are provided in Table 2. To illustrate the presence of climate change within the parks, we note the historic averages (1901-2014), the averages for the years in which our analyses were preformed (1979-2014), and recent averages (2000-2014).

[INSERT TABLE 2 HERE]

Zion National Park has and continues to be the most visited national park within the state, receiving an average of nearly 185,000 visitors a month since 1979. The past fifteen years has seen average monthly visitation climb to over 222,000. Canyonlands National Park has received the fewest visits, averaging 27,500 visits a month since 1979. Visitation to the park has increased steadily, averaging over 35,000 between 2000 and 2014.

All of the parks have experienced warming temperatures since the early 20th century, with average monthly mean temperatures rising between 0.6 C (Arches and Canyonlands) and 1.1 C (Bryce Canyon). Average monthly minimum temperatures have risen between 0.3 C (Arches and Canyonlands) and 1.3 C (Zion). Average monthly maximum temperatures have risen between 0.7 C (Capitol Reef and Zion) and 0.9 C (Canyonlands).

The landscapes of each park, excluding Canyonlands, have also become drier over the past 115 years. Mean monthly precipitation has declined between between 0.4 mm per month (Arches) to 1.8 mm per month (Zion). The landscape of what is now Canyonlands National Park has actually received more precipitation in recent years, averaging 22.7 mm per month since 2000 (up from a historical average of 22.3 mm per month).

The correlations between each of the ten climate variables and monthly visitation for each study park are illustrated in Figure 3. A positive correlation is noticeable for all of the temperature variables, with monthly average daily mean, minimum, and maximum temperatures showing the most distinct relationship with visitation; more variability can be seen in the correlations using both diurnal temperature range and potential evapotranspiration. Both of the precipitation variables (mm of precipitation per month and number of wet days per month) appear to be weakly related to monthly visitation, if at all. As might be expected, both the frequency of frost days and the percentage of cloud cover appear to be negatively related to visitation.

[INSERT FIGURE 3 HERE]

Common Correlated Effects Estimation

Coefficients estimated for each of the ten climate variables with the panel time series regression models are summarized in Table 3 (Columns 2 – 4). All four derivations of the temperature variable (monthly average daily mean temperature, monthly average daily minimum temperature, monthly daily average maximum temperature, and diurnal temperature range) were consistently and positively related to visitation (Coef. = 0.002 – 0.006; p = 0.002 – 0.004). Collectively, models including a temperature variable performed well, explaining between 56.2 percent (diurnal temperature range) and 82.1 percent (monthly average daily maximum temperature) of the variance in observed monthly visitation. Both of the precipitation variables (mm of precipitation per month and wet day frequency) were not significantly related to visitation (Coef. = 0.000 – 0.002; p = 0.425 – 0.476). When a precipitation variable was included in the model, almost none of the variance in monthly visitation was explained ($R^2 < 0.001$). Of the other climate variables explored, only potential evapotranspiration was significantly related to monthly visitation in the common correlated effects estimation (i.e., in the model with data from all five panels (parks) included). Potential evapotranspiration was positively and significantly related to monthly visitation (Coef. = 0.027; p = 0.005). This is logical, given the fact potential evapotranspiration is a derived measure of monthly and annual mean temperatures (Bonan, 2002). Frost day frequency, percentage cloud cover, and vapor pressure were not significantly related to monthly visitation (Coef. = -0.007 – 0.027; p = 0.129 – 0.383). However, the regressions including these variables as predictors did explain a good proportion of the variance in monthly visitation (R^2 = 0.507 – 0.854).

[INSERT TABLE 3 HERE]

Panel-Specific Estimation

Looking beyond the common correlated effects estimations, we see more divergence in how the local climates of each individual park is related to that park's monthly visitation. Results from the panel-specific estimations are summarized in Table 3 (Columns 5 – 19); full model results are provided in Supplemental Table 2. The models suggest that temperature (monthly average daily means, minimums, and maximums) is positively and significantly related to monthly visitation for every park except Capitol Reef. Diurnal temperature range was also significantly related to monthly visitation at the two adjacent parks located in eastern Utah (Arches and Canyonlands), but not for the three other parks within the state. Canyonlands National Park appears to be an anomaly, with no observed relationship between temperature and visitation.

While precipitation, measured either via mm of precipitation per month or the number of wet days per month, was a very poor predictor of monthly visitation in the estimation using data from all five parks, the park-specific estimates suggest that it is related to visitation at some, but not all, of the parks within the state. The panel-specific models suggest precipitation (mm per month) is positively related to visitation at both Bryce Canyon and Capitol Reef National Parks (Coef. = $-2.4e^{-4}$ – 0.001; $p < 0.016$). The number of wet days per month was also positively related to visitation at Bryce Canyon and Canyonlands (Coef. = 0.005 – 0.010; $p < 0.001$). It appears that while precipitation is a poor predictor of visitation across park units, it can be a good predictor of visitation within select units.

Of the other climate variables explored, potential evapotranspiration was positively related to monthly visitation at all of the parks (Coef. = 0.010 – 0.063; $p < 0.063$) with the exception of Capitol Reef (Coef. = 0.010; $p = 0.200$). Both frost day frequency and percentage cloud cover are related to monthly visitation at some parks, even though these climate variables are not good universal predictors of monthly visitation. Frost day frequency was negatively and significantly related to monthly visitation at each study park (Coef. = -0.012 – -0.004; $p < 0.001$), with the exception of Arches. Percentage of cloud cover was significantly and positively related to monthly visitation within Bryce Canyon (Coef. = 0.006; $p < 0.001$), but it was not related to visitation at any of the other national parks (Coef. = $2.8e^{-5}$ – 0.006; $p > 0.117$). The final variable explored in the panel-specific models, vapor pressure, was significantly related to monthly visitation at all five national parks (Coef. = -0.029 – 0.005; $p < 0.042$). Recall however, that this variable was not significantly related to monthly visitation when data from all five park units were used (Coef. = -0.007; p – 0.383). This apparent contradiction is the product of vapor pressure being positively related to monthly visitation at Arches and Capitol Reef and negatively related to monthly visitation at Bryce Canyon, Canyonlands, and Zion. Whether or not a climate variable is a useful predictor of visitation depends on the geographic scale of the analysis. Some predictors, like precipitation and vapor pressure, may be useful at local, park-specific scales, even though their effects on visitation are washed out at larger, regional or nationwide analyses.

Discussion

A Wide-range of Climate Variables Can Affect Visitation

We began this investigation with two primary objectives, the first of which was to determine how a broad set of climate variables affect visitation across a tourism system. The majority of previous research on the relationship between climate and visitation has relied heavily on mean temperature as the primary factor affecting tourists' travel decisions; this is especially true of analyses of national and/or international travel patterns given the ubiquitous availability of temperature data (Bigano et al., 2006). Across this research, mean temperatures are almost always positively associated with visitation (e.g., Fisichelli et al., 2015; Hewer et al., 2016), suggesting a continued warming in mean air temperatures will contribute additional visitation pressures on tourism destinations. This is in addition to the pressures associated with growing populations and other potential drivers (White et al., 2016) . The analysis presented here aligns with previous research exploring temperature as a driving factor shaping tourists' travel decisions. Across our study parks, we found a consistent positive relationship between the monthly average daily mean temperature and visitation levels. With the exception of Capitol Reef National Park, this relationship was highly significant ($p < 0.001$). Across all five parks, the use of monthly average daily mean temperatures explained a large proportion of the variance in monthly visitation rates ($R^2 \geq 0.814$).

While the monthly average of daily mean temperatures was a very good predictor of visitation to our study parks, it was not the best predictor. The monthly average of the daily maximum temperatures explained slightly more of the variance in visitation across the five parks ($R^2 \geq 0.821$). The reason for this may be attributable to the direct role daily maximum temperatures play in tourists' travel decisions. The climate averages of destinations are almost always presented through an average of daily maximum temperatures (as well as an average of daily minimum temperatures). When a tourist is considering different possible destinations, they rarely think about what the average daily temperature will be at each destination. Rather, individuals plan their travel behavior around the temperatures during the times when they will be most active; for most, this is mid-day or early afternoon when temperatures are at their highest. Future research may find a stronger behavioral response to average maximum daily temperatures relative to average mean daily temperatures, as our investigation did. We would expect future research to find similar patterns, especially if the analysis if focused more specifically on peak summer season visitation, which is more sensitive to temperature variations (Falk, 2014, 2015).

Our analysis was conducted across all twelve months of the year, which likely masks some of the predictive power of the maximum temperature variable.

In addition to providing a more direct connection between climate and tourists' travel behavior, the average of maximum daily temperatures can illustrate the presence of a negative relationship between temperature and visitation. Previous research has suggested that the presence of a positive relationship between temperature and visitation rates only holds up to temperatures between 25 and 33 C (Fisichelli et al., 2015; Hewer et al., 2016). Beyond this, visitation declines because it can become uncomfortable to be outside, especially at locations where many visitors are highly physically active (such as national parks). We observed this inverse u-shape relationship between temperature and monthly visitation for three of our study parks. At both Capitol Reef and Canyonlands National Parks, monthly visitation declines beyond an average maximum daily temperature between 25 and 33 C. At Arches, visitation tends to level off once maximum daily temperatures hit this threshold. These patterns can clearly be seen in Figure 3. This inverse u-shape relationship was not noticeable in the data from either Bryce Canyon or Zion National Park, suggesting the relationship is not universal and that there may be confounding mitigating factors present. Both Bryce Canyon and Zion National Parks are characterized by seasonal streams and steep canyons (as well as slot canyons in Zion); both of these characteristics result in milder conditions than the actual temperature suggests. The unique geophysical characteristics of these parks (as well as others like them), may allow visitation rates to continue rising even with maximum daily temperatures well above 25 C. These findings have both theoretical and managerial implications.

In regards to theory, it well understood that tourists are more more capable of adapting to climate change than tourism destinations (Scott, Amelung, et al., 2008). Tourists can easily avoid destinations impacted by climate change by altering the timing or destination of their travel. Large tourism destinations however, especially those with large capital investments and immobile assets like national parks, have less adaptive capacity. The adaptive capacity of large tourism destinations is highly variable. Mather, Viner, and Todd (2005) suggest this variability is a function of a variety of factors including the physical environment and the topographical characteristics of specific destinations. Our data offer empirical support for this suggestion as it appears the seasonal streams and steep canyons which characterize the outdoor recreation opportunities within Bryce Canyon and Zion make those national parks more capable of adapting to a warmer and drier climate. This is one small empirical example of how large tourism destinations have highly variable adaptive capacities. Future research is needed to explore other factors which might affect this adaptive capacity (e.g., the nature of the tourism markets being served, the types of tourism facilities and attractions offered, etc.) (Mather et al., 2005).

As for management, knowing the unique geophysical characteristics of some parks may allow for more visitation, even with maximum daily temperatures well above 25 C, may create additional challenges for destinations like Bryce Canyon and Zion which are already struggling to maintain their recreational infrastructure under extremely large visitation pressures (e.g., Zion National Park alone received 4.3 million visits in 2016). Zion National Park, for example, receives over 400,000 visitors a month in the peak summer months of July and August (National Park Service, 2017) and also has a $70 million maintenance backlog. Destinations like Zion and Bryce Canyon, whose unique geophysical characteristics and outdoor recreation opportunities allow visitors to feel cooler even as temperatures rise, are not likely to see a plateauing of summer visitation in the near future. Destinations like this will continue to face the daunting management challenge of accommodating more and more visitors with stagnant operational budgets. One potential solution is for the state's tourism campaigns to shift attention from the national parks of Utah to other attractive destinations and activities like the state's outstanding skiing attractions. The Utah Office of Tourism has recently began to head in this direction. In 2016, they launched "The Road to Mighty" ad campaign (Utah Office of Tourism, 2017). The campaign highlights the many other attractions in Utah such as it's state parks and national monuments. However, the popularity of Utah's national parks does not seem to be going away anytime soon, and neither are the challenges of managing park resources and visitors.

Aside from the temperature variables already discussed, our analysis explored the relationship between a wider array of climate variables and visitation than has been common in previous research. Principal among these were a set of precipitation variables, mm of precipitation per month and the number of wet days per month. By and large, these variables were very poor predictors of visitation. However, our panel-specific time series regression for Bryce Canyon National Park did reveal a positive and significant relationship between both precipitation variables and monthly visitation. Initially, this result may seem counterintuitive as one would assume wetter weather would either drive visitors away from the park or make it more likely for them to stay inside at their hotels outside of the park. Bryce Canyon is the only park within our sample that offers snow-based outdoor recreation opportunities, including groomed trails for cross-country skiing and snowshoeing. Data from Bryce Canyon illustrate consistent visitation in the winter months and, as illustrated in our results, visitation that increases when more snow is present. Future investigations into the relationship between climate and visitation should not disregard the possibility of precipitation being a significant factor shaping visitors' travel decisions. Smaller-scale (e.g., park specific) and activity-specific (e.g., beach recreation, skiing/snowboarding, etc.) research is much more likely to find a behavioral response to precipitation. For example, recent research has found that extreme dry conditions can lead to notable declines in visitation to mountainous national parks in the western U.S. (Jedd et al., 2017).

One of the limitations of our investigation is the inability to examine whether the relationships observed between climatic conditions and visitation are similar for both local visitors and distant visitors. Previous research suggests climate change affects the travel behaviors of international and domestic visitors differently, with international visitors being more likely to visit a destination regardless of the weather conditions during their travel (Scott, Gössling, & Hall, 2012). Domestic visitors, especially those living closer to the destination, are able to alter the timing or duration of their visit more easily than international visitors. Previous research does not provide much insight beyond these logical and intuitive differences. More focused research is needed, especially for prominent tourism destinations like some U.S. National Parks, which receive a substantial amount of visitation from both domestic and international markets.

Scale Matters in Analyses of Climate and Visitation

The second objective of this investigation was to identify which climate variables affect visitation across an entire tourism system and which climate variables only affect visitation at specific destinations. By conducting our analyses at two distinct scales, across a regional recreation system consisting of five national parks and at each of those national parks individually, we have been able to ascertain whether there is a difference between the individual climate variables that are regionally-significant drivers of visitation and those that are locally-significant drivers of visitation. Our analyses illustrate that scale matters in analysis of the relationship between climatic conditions and visitation patterns. All of the temperature variables we examined were good predictors of visitation at both a regional scale and the scale of most individual park units. However, for one park (Capitol Reef) the relationship between temperature and visitation was not statistically significant. This suggests that the positive relationship between temperature and visitation, while being commonly found in mid-latitude tourism destinations, is not a universal maxim. Many destinations, like Capitol Reef, may have visitation trends that plateau in the summer months due to a variety of factors. The landscape of Capitol Reef is a high desert with little vegetative cover and few streams. These geophysical conditions can make the hot summer months uncomfortable, resulting in a monthly visitation profile that is characterized by stagnant visitation between the months of May and September. This finding is noteworthy and highlights the need for regional climate-specific tourism policy and resource management approaches to not assume that temperature and visitation are always positively related. Careful consideration needs to be given to local geophysical, institutional, and social factors that may mediate the relationship between temperature and visitation. In the same vein, our analyses also revealed other climate variables that were poor predictors of visitation across the region, but that were highly significant predictors of visitation at the scale of individual parks. Precipitation (mm of precipitation per month), frost day frequency, and vapor pressure were not significantly related to monthly visitation in our regional model (i.e., using data from all five parks). However, they were significantly related to visitation at individual park units. This finding suggests the need to cast a wide net in considering the specific climatic conditions that influence visitation across a recreation system. Collectively, these findings highlight the need for future research, climate-related policy formation, and resource management planning to be vigilant of the fact that scale matters in the relationship between climate and visitation.

Conclusion

By exploring how a broad set of climate variables affect visitation across a tourism system, our analysis has demonstrated that different climate variables affect visitation to managed natural areas in different ways. The relationship between specific climate variables and visitation is a function of the geophysical characteristics and recreational opportunities that are available at specific destinations. Climate is obviously related to visitation patterns, but how and why it is related to visitation patterns is a product of a more diverse array of factors (e.g., vegetative cover, geographic relief, types of recreational activities supported, etc.) than are commonly considered in research on climate and tourism.

By identifying which climate variables affect visitation across an entire recreation system and which climate variables only affect visitation at specific destinations, our analyses demonstrated how the spatial scale of an analysis yields quantifiably different results. Ignoring the issue of spatial scale in climate-focused visitation research can result in misinformed climate-related policy and in poorly developed resource management frameworks. Future investigations need to be vigilant in considering how the scope of their analysis informs the inferences that can be made, and consequently, the types of policies and management decisions that can be recommended by their analyses.

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